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Dr. BOERHAAVE'S Academical Lectures ON THE Theory of PHYSIC.

BEING

A Genuine Tranſlation of his

INSTITUTES

AND

Explanatory COMMENT,

Collated and adjuſted to each other, as they were dictated to his STUDENTS at the Univerſity of *Leyden*.

VOL. IV.

Containing the Oeconomy of the External and Internal Senſes, Sleep, and Reſpiration.

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Of the Touch [1] *or Feeling.*

§. 481. THE corporeal Organs with which we are ſaid to examine Bodies by the Touch, are ſoft, pulp-like nervous *Papillæ* [2], *medullary* [3], and of a pyramidal Shape, ariſing from the ſubcutaneous Nerves, firſt caſting off their exterior Membranes, and render'd very ſoft; whence they become very ſenſible, being continually *moiſtened* [4] with a very thin Liquor, and defended with a very thin and denſe or compact *Cuticle* [5], without impairing their Senſibility, lodged under the Cuticle in Furrows and *Cavities* [6], and capable of contracting and *erecting* [7] themſelves in thoſe Parts, where the Senſe of *Touch* [8] is the moſt exquiſitely performed, as in the Tongue, Ends of the Fingers, *&c.*

[1] By the Touch in this place, we do not underſtand that univerſal Senſe, without which there is not any Part of the Body to be found; but we here intend that particular Senſe which is exerciſed by the Ends of the Fingers, as by a particular Organ or Inſtrument. Nor yet do we here ſpeak of that Change in our Thoughts, which ariſes from the Idea of Cold, Roughneſs, or the like;

for we cannot determine any thing with Certainty concerning thoſe Changes: but we here intend that Change in the corporeal Organ, from whence ariſe in the Mind the Ideas of a cold, rough, or moiſt Body, *&c.*

[2] That theſe are the proper Organ of Touch, is evident from a Deſtruction or Loſs of that Senſe, which follows from a Compreſſion, Eroſion, or Burning, ſo as to deſtroy the Papillæ. If the reticular Body is injured by Fire in the Ends of the Fingers, the Papillæ are deſtroyed, and the Senſe of Touch is aboliſhed. Theſe Papillæ ariſe from the Nerves, and tranſmit the Impreſſions which they receive to the Nerves, and by them to the Brain, where at length the Idea of Touch or Feeling is excited.

[3] All the Nerves of the Skin which are deſtined to the Senſe of Touch, have that Senſe but in a very dull manner, ſo long as they are covered with the thick Coats or Integuments; but when thoſe membranous Coverings are depoſited, and form the reticular Body, the Nerves are then naked, and of ſo ſoft a Texture, that they reſemble a Mucus, yet are they in that State the more ſenſible. Hence we find that not the Meninge, but the Medulla, is the Organ of Senſation; for upon opening the Skull of a living Dog, and puncturing the Meninges, no great Diſorder is obſerved in the Animal; whereas if the Medulla itſelf be injured, the Animal is then immediately convulſed, and ſtaggers.

[4] This is a great Uſe of the Perſpiration diſtributed throughout the whole Skin: For neither could the Nerves be ſupplied with any Moiſture, but what has been extravaſated; nor yet could the Nerves be capable of performing their reſpective Senſes, if they were not moiſtened. When the

Skin

Skin is dry, the Senſe of Touch is either depraved or aboliſhed. They who ſleep with their Mouth open, are not capable of diſtinguiſhing any thing by the Taſte in the Morning; for the admitted Air has dried up the Tongue. When the Noſe is ſtuffed up with Duſt, the Senſe of ſmelling ceaſes.

[5] If the Nerves were naked, they would not be capable of preſerving their Continuity but for a very ſhort time; and therefore Nature has given them this Defence of the Cuticle, which is a very thin Membrane, that it might not exclude the Impreſſions of ſenſible Objects; but very compact or firm, that it might the better defend or ſecure the ſoft naked Nerve which lies under it. The Senſe of Touch is moſt perfectly exerciſed under theſe Circumſtances. The naked Papillæ being gently touched with a Feather, excite an intolerable Itching: nor is there any other Cauſe of that exquiſite Senſe and moſt violent Itching which is obſerved in the Glans Penis, and in the female Organs, more than the numerous and thick-ſet Papillæ. But the Cuticle covers all the naked Nerves, even where the Skin itſelf is abſent. We call the Mouth that Fiſſure or Diviſion betwixt the Lips, which in the Fœtus is larger than uſual, extending itſelf almoſt to the Ears in an Embryo of four or five Months old. Hence it is that Infants, who are born after ſeven Months Geſtation, have their Mouth opening wider; whereas thoſe of nine Months have a leſs and nearer Mouth; for the Fiſſure is continually and gradually diminiſhed by the conjoining Skin. In the Mouth therefore the Skin terminates at the Lips; whereas the Cuticle, which is extended much farther than the Skin, covers the whole Lips internally. If this thin Cuticle, or Epithelium of *Ruyſch*, is taken off by Maceration and Shaking, the Papillæ remain naked,

ked, and ſtick out on all Sides like Hairs. If theſe Papillæ are injured after the Cuticle is excoriated or vitiated, the worſt Maladies follow with intolerable Pains.

[6] Namely, the Wrinkles of the Skin running variouſly together, and leaving triangular, quadrangular, or pentagonal Spaces differing in ſeveral Parts of the Body. Theſe Sulci or Furrows of the Skin have the Cuticle inflected betwixt them, under which there are placed two Orders of nervous Papillæ. Betwixt theſe Furrows are ſeated the exhaling and ſudoriferous Veſſels, together with the Hairs; all which has been very well obſerved by *Malpighi*.

[7] *Malpighi* obſerved in the Body of a Perſon, whoſe Skin was not in the leaſt callous, that after Dinner, in a warm Air, he could perceive by the Microſcope in the Ends of the Fingers, a great Number of ſmall round Bodies like Warts (which were the nervous Papillæ) riſe up ſuddenly, when the Perſon endeavoured, as it were by the Influence of his Will, to examine any thing accurately by the Touch. But in the Tongue this Experiment is more eaſy and conſpicuous; for if a Perſon ſtands faſting before a Looking-glaſs, and a little Sugar is offered to the Tongue to be taſted, you will plainly perceive the whole Surface of the Tongue beſet with ſmall Tubercles. Snails furniſh us with a notable Inſtance of this Extenſion or Protuberance. For when theſe ſmall Animals go forward, they frequently put out their Horns to ſearch out what Dangers may lie in the way; their Eyes being alſo fixed in the Tips of their Horns: but when the timorous Reptile meets with any hard Obſtacle, the Horns are immediately retracted. The ſame thing takes place in the nervous Papillæ, only it is much leſs conſpicuous.

The

[8] The Organs of this Senſe are the ſubcutaneous Nerves, which having depoſited their Coverings or tough Skins, form with them one continued Integument, whoſe Veſſels are ſo ſmall, that they cannot be render'd viſible by any Inflammation, Injection, or even by the Microſcope; but immediately under this Cuticle is ſpread a ſofter Subſtance, known by the Name of the reticular Body, which is unequally ſurfaced, having Furrows which intercept Spaces, in the Cavity whereof are lodged the Papillæ: nor do the Furrows belong to the Cuticle, but to the reticular Body.

§. 482. But with reſpect to theſe Papillæ, it is very remarkable and ſurpriſing, that tho' they are diſpoſed in a perpendicular Poſition with reſpect to the Skin in the other Parts of the Body, yet at the Ends of the Fingers and Toes they lie *extended* [1] according to the Length of the Joints; from whence they are continued and folded up in the *Cuticle* [2], as in Sheaths, in which becoming dry, they are condenſed into the Nails; and by means of the conſolidated or condenſed cutaneous Veſſels, ſerve to *defend* [3] the Papillæ, and are *fitted* [4] to prevent them from growing callous.

[1] We obſerve firſt Striæ, which on the outſide and lateral Parts of the Ends of the Finges, run parallel; but betwixt theſe Striæ are diſpoſed the Papillæ, not perpendicularly erected, but diſpoſed one over the other in Strata. When theſe Striæ touch the Nail, there the exterior Papillæ, with the cutaneous Veſſels and Cuticle itſelf, are extended into right Lines, and hardened into the Sub-

ſtance of the Nail itſelf; but the remaining lower Striæ, which are placed under the Nail, go on cloſe together in right Lines, and cover the Nail. But thoſe Papillæ which are continued laterally to form the Nail, diverge and ſpread themſelves on each Side towards the Fingers; upon which they form thoſe ſpiral Lines, which are peculiar to the Skin in the Fingers Ends.

[2] To this adhere the Nails; and the Nails ſeparate or come off with that Glove of the Cuticle, which Anatomiſts take off from the Hands of a Fœtus by Maceration.

[3] Under the Nails the naked Papillæ are extremely ſenſible; and by cutting the Nails too cloſe, they occaſion not ſo much a Pain, as an intolerable Uneaſineſs in feeling.

[4] In moſt Animals there is ſtill another Uſe of the Nails, of which the human Species are likewiſe not wholly deſtitute; for if we neglect our Nails they grow out into long Cones, like unto the Talons of an Eagle, whenever they are allowed to grow on without cutting for a conſiderable time. Thus it is with the *Chineſe*, who ſuffer their Nails to grow from a Principle of Religion, and for a Mark of Dignity. But in all rapacious Brutes, whether Quadrupeds, Birds, or Inſects, the Nails are given as Inſtruments of Safety for defending themſelves, and making War upon others.

§. 483. The Touch then is performed by applying the End of the *Finger* [1] to the ſenſible Object which is to be examined, and while the Papillæ are erected or *extended* [2] by the Attention of the Mind, by *gently* [3] rubbing them over the Surface of the Object, a certain *Motion*

tion [4] is impreſſed upon thoſe extended Papillæ; the Effect of which is conveyed to the common Senſory, where it excites in the Mind the *Idea* [5] of *Heat* [6], Cold, Moiſture, Drineſs, Softneſs, Hardneſs, Smoothneſs, Roughneſs, Figure, Motion, Reſt, *Diſtance* [7], *Titillation* [8], *Itching* [9] and Pain.

[1] This might be performed as well by the Toes as the Fingers, if we did not continually walk in Shoes, and render the Papillæ callous or inſenſible by the continued Preſſure of the Body.

[2] At leaſt they are erected when the Mind is attentive, if they are not extended or thruſt out.

[3] The whole Touch is the Reſiſtance of the Body which we feel. If this Reſiſtance is moderate, the Feeling is diſtinct; but if violent, a Pain ariſes in the ſenſitive Organ: thus when the Cuticle is off from the Finger, we do not diſtinguiſh the Qualities of Bodies, but are only ſenſible of a Pain in the Organ.

[4] Motion is nothing more than a Change of Surface; but yet the ſame being conveyed by the contiguous Nerves to the Mind, does there impreſs its certain and determinate Idea.

[5] The Organiſt of *Amersfort*, concerning whom Mr. *Boyle* writes, that he had ſo exquiſite a Touch that he could diſtinguiſh Colours and black Letters by Feeling, when he was faſting and the Seaſon of the Year not too dry.

[6] We call a thing warm or tepid, which has the ſame Degree of Heat with that of the human Body; and hot when the Heat exceeds that of our Body: but that which has a leſs Heat than our Body is ſaid to be cold. This Senſe of Heat is perceived by the whole human Body, but is more

exquiſite in the Ends of the Fingers and Tip of the Tongue; that is, wherever the nervous Papillæ abound or are moſt numerous.

[7] This is a ſurpriſing Obſervation propoſed by *Carteſius.* A blind Man or any other Perſon in the moſt profound Darkneſs will be in no Danger of running againſt hard Bodies, provided the Hands are armed with Sticks croſſing each other; the Ends of which ſtrike againſt the Bodies or Obſtacles to be avoided. From hence it appears, that there is a kind of natural Trigonometry in us, and that our Bodies are taken for the Baſe of the Triangle, the Sticks for the Sides, and the Mind concludes from the Vicinity of the greater Angle of the Vertex concerning the Nearneſs of the Body or Object; and from the Smallneſs of the ſame Angle it judges the Object to be more remote.

[8] For thus we call that State of a Nerve in which it is ſo far extended, that a ſmall Degree of greater Tenſion will excite Pain. The Vellication which we perceive from a Feather in the Noſe, is not Pain, and yet it is intolerable, inſomuch that being continued, the Vellication is communicated to the larger Nerves and then Convulſions are excited.

[9] Nothing is more pleaſing than this Senſe, nor is there any other corporeal Pleaſure. It exceeds Titillation in a ſmall Degree of greater Tenſion in the Nerves, which is ſuch in this Caſe, that by continuing or a little increaſing the Nerve may be broke. It is very well known how ſevere a Pain follows a violent Itching. In the Itch the Cuticle being elevated leaves a Cavity betwixt itſelf and the Papillæ, full of an acrid Liquor, with which the Papillæ are ſtimulated; and from thence ariſes ſuch an intolerable Itching, that I have ſeen ſome Men faint away by the Exceſs of Pleaſure which they

they have from thence received. But if the itching Part is ſo intolerable from the Senſe, that it obliges the Perſon to ſcratch with the Nails, a continual Pain follows from a Diſſolution of the Nerves. Thus nearly has Nature united Pain to Pleaſure.

§. 484. From hence it appears, why we feel *Pain* [1] by touching an Object after the Cuticle has been abraded by rubbing, macerating, waſhing or burning? why the Touch or Feeling is deſtroyed, when the Cuticle is render'd thick, hard and *callous* [2], or corrupted by a Scar? what is the Cauſe of that wonderful Motion of the Body from trembling, and of that diſagreeable Numbneſs, gradually tending to an Inſenſibility, which ariſes from the Fiſh called *Torpedo* [3]? why the *Pain* [4] is ſo ſevere on the Inſide of the Nail attached to the ſubjacent Skin, and at the Roots of the Nails? and laſtly why the Senſe of Touch is moſt exquiſite where the *Nails* [5] grow, and where the Sulci or Furrows of the Cuticle are *ſpiral* [6]?

[1] Becauſe then the ſmall Nerves or Papillæ being render'd too ſenſible, are eaſily deſtroyed. Such an intolerable Soreneſs or Incapacity of Feeling we obſerve after the thin Skin has been abraded from the Lips; and likewiſe after a Nail has been tore off, and after large Calloſities of the Cuticle have been caſt off, when the Patient has recovered from an ardent Fever.

[2] This is no more wonderful than if one ſhould ſay, that a Hand in a Glove cannot feel with ſo much Accuracy as if it was naked; for a Callus like

like a Glove prevents the Action of the ſenſible Object upon the Nerves. The Hand of a tender Girl being pricked with a ſmall Needle, continually bleeds to a conſiderable Quantity; whereas the ſame Puncture would not be perceived in the hard Hand of a laborious Man. Hence the Blackſmiths of *Leyden* have ſuch thick Calloſities in their Hands, that you may ſometimes ſee them handling the red hot Iron; the Callus at the ſame time burning, ſmoaking and ſtinking, and all without any Senſe of Pain. But a Callus is a Tumor ariſing from a Complication of the cutaneous Veſſels continually preſſed together until they cohere in ſeveral Strata.

§ *Ariſtotle* and *Theophraſtus* give us the Hiſtory of a Fiſh reſembling a Skate, which being touched either by the Hand, a Stick, or even with a Net ſtupifies or benumbs the Senſe of Feeling in a Perſon, and ſometimes when the Cauſe is ſtronger excites Convulſions. But ſome of the Moderns eſteem theſe Accounts of the ancient Hiſtorians as fabulous; and yet the lateſt Travellers through both the *Indies* confirm the whole Account. The Theory of this wonderful Phænomenon has been given us by *Borelli*; namely, that there is a very ſtrong and tenſe Muſcle under the whole Skin of this Fiſh, which contracts when the Fiſh endeavours to eſcape from the thing that touches it, and ſoon after is ſwelled or elevated again; both which Motions are performed reciprocally with ſo much Velocity one after another, as to excite thoſe troubleſome Tremors, which even diſturbs the common Senſory of any Man: whereas nothing of this happens when the Fiſh is dead. To me indeed the whole Affair ſeems to be no great Difficulty. When a Saw which is very tight and ſhort is ſharpened by the File drawn ſwiftly over it, or if a glaſs Ball is cut or ſawed

as

as it were by the Knife, or laſtly when a muſical Chord very ſhort and tenſe is moved by the Bow, ſuch an intolerable ſcreaking Noiſe ariſes as ſets the Teeth on Edge; ſo that every one would gladly get rid of it at any Price. But yet in this Caſe nothing more happens than a Tremor in the auditory Nerve, correſponding to the Tremors of the Iron which is filed. By the ſame Reaſon therefore when the Torpedo-fiſh excites moſt ſwift Tremors by its Muſcles, the Nerves of the Perſon who touches the ſtuporiferous Animal are excited into Tremors of the like Nature. Nor is it wonderful that this Effect ſhould be communicated through Sticks, or even through the Nets themſelves: for if a long Stick or Pole be ſuſpended by the Teeth, and any Perſon ſtrikes the Pole at the other End, the Stroke will be perceived as ſtrong in the Head as if it was immediately inflicted upon that Part.

[4] The Papillæ which lie naked and parallel to each other under the Nails, are continued like Scales over each other, and proceed in that manner in great Numbers to the End of the Finger. If theſe Papillæ are careleſsly expoſed by cutting off too much of the Nail, a very acute and troubleſome Senſation will ariſe whenever the Finger touches another Body; which yet is ſomething different from Pain, and gradually goes off as the Nail grows up, and repairs the former Covering of the Papillæ.

[5] Becauſe there the Papillæ are diſpoſed like Scales or Tiles. When an Inflammation is there ſeated, a moſt intenſe Pain follows, which a prudent Surgeon allays by making an Inciſion through the Nail, without which the Pain might ariſe to ſuch a height, as even to produce Convulſions themſelves.

For

[6] For here they are more numerous, whereas in other Parts of the Body they are not ſet ſo thick together, but lie ſcattered at greater Diſtances. To which add, that in the Fingers Ends there are neither Muſcles or Fat, but only a Sort of ſpungy Fleſh, throughout which the Papillæ are diſperſed in great Numbers.

Of the TASTE.

§. 485. ON the Back of the *Tongue* [1], eſpecially towards the Point and Sides thereof, under its *Skin* [2] lie obtuſe Papillæ, which are obſerved of *three Kinds* [3], and which erect themſelves apparently in a Tongue that is living, warm, moiſt and thruſt out of the Mouth to taſte any ſapid Body, more eſpecially when a Perſon is faſting; but in dead Bodies theſe Papillæ of the Tongue diſappear. They ariſe from the nervous Body which lies upon the muſcular Fleſh of the Tongue, lodged in a kind of fine cellular Membrane, containing a little Fat, from whence they riſe up and perforate the reticular Body, directly in the ſame Manner as we obſerved before in the Skin; (at §. 417, 418.) they are then confined in erect Capſules or *Caſes* [4] continued from the exterior Membrane of the Tongue, by which they are defended againſt the Roughneſs, Acrimony, and Heat of every thing taken into the Mouth. Theſe Vaginæ

or

or Capſules are full of Pores, and *project* 5 or ſtick out in ſuch a manner, that the Food or Drink by *Preſſure* 6 acts principally upon them, that they may receive the Impreſſion of the ſapid Object.

[1] The principal Office of this ſmall Member is for the Taſte, its ſecond Uſe is to aſſiſt in Deglutition, and its third to modulate the Speech or Voice.

[2] This Name I give to that Integument which is ſpread upon the Back and Root of the Tongue, upon the middle of which it is thickeſt, and grows gradually thinner towards the ſides and tip, being in all other reſpects like the Skin itſelf: but below in the Belly of the Tongue, it is of quite a different Fabric. When this Skin is taken off, which is moſt eaſily performed by boiling, the Tongue appears very rough, and beſet on all Sides with protuberant Papillæ covered with the reticular Body of *Malpighi*, which receives the Papillæ into its Cavities. At the Mouth or Diviſion of the Lips the Skin terminates as if it was cut off; but then the Cuticle is continued over the Lips, which appear very red from their numerous ſmall Veſſels, and which bleed plentifully whenever the Cuticle is peeled off. The ſame Cuticle continues alſo to cover the Cheeks internally, together with the Gums even to the Root of the Tongue, where it is continued thin at the Sides; but on the Back of the Tongue it is much like Leather, or callous, and in Thickneſs almoſt equal to the eighth Part of an Inch: for in the middle of the Back of the Tongue the Aliments are preſſed againſt the Palate; from whence it is that the Tongue itſelf and Perioſtæum of the Palate-Bones become callous by this Preſſure and Attrition, which being little or nothing

nothing upon the lower Part of the Tongue, the Skin is there extremely thin. This thick Integument therefore of the Tongue, alſo forms the Coverings of the ninth Pair of Nerves.

[3] Some conical, others like Muſhrooms, and others again inflected like Arches. Thoſe Papillæ which are the largeſt, moſt obtuſe and hard, are the leaſt numerous, are comprehended in particular Cavities of their own, and are ſeated at the Root of the Back of the Tongue; while thoſe which are ſmall, ſlender, and arched, are obſerved the moſt numerous; while on the Sides of the Tongue, the Papillæ are diſpoſed in a ſort of Medium betwixt the two former.

[4] The Tongue ought to be ſenſible for the Taſte, and yet not capable of being injured by a ſlight Violence. Hence it is both furniſhed with numerous Nerves, and at the ſame time defended with very thick Coverings. The covered Papillæ lie concealed like Horns perforating the Pores of a Spunge. Hence a Perſon is able to ſwallow Drink almoſt ſcalding, namely, by reaſon of the Thickneſs of this Covering of the Papillæ.

[5] The Tongue of a hungry and faſting Perſon appears beſet with rough Tubercles, whenever any Food is offered to his Sight, which can excite the Appetite. But when the Taſte is deſtroyed, and the Perſon is dead, the Tongue looks ſmooth; and hence it is that the Papillæ are ſcarce demonſtrable in the anterior Part of a dead Tongue, ſo that Anatomiſts uſually take the Tongue of an Ox to ſhew theſe Papillæ.

[6] When the Food is preſſed too ſtrongly againſt the Tongue, no Taſte ariſes; but a Perſon will rightly diſtinguiſh the Taſte of a ſapid Body, by gently preſſing it againſt the Surface of the Tongue, thruſt up againſt the Palate.

§. 486.

§. 486. And it appears probable that theſe Papillæ, which are ſo very numerous, ariſe from the *ninth* [1] Pair of *Nerves* ſent to the Tongue, and diſtributed through it; but that a Branch of the fifth Pair of Nerves is alſo ſent into the *Muſcles* [2] of the Tongue for its voluntary Motions, diſtinct from that of the Senſe of taſting, as we obſerve in other Parts.

[1] For this Pair of Nerves belongs only and entirely to the Tongue; whereas the fifth Pair is diſtributed to various Muſcles, and likewiſe to other Senſes; as, for Inſtance, to the Noſe.

[2] No Part of the Body is more nimble or active than the Tongue: It is not loaded with Fat, and yet the adipoſe Membrane is interpoſed betwixt the ſeveral Strata of its muſcular Fibres; but in this adipoſe or cellular Membrane is the Seat of great Diſorders; and thence it is that ſkilful Surgeons are ſo much afraid of Injuries of the Tongue, ſuch as Wounds, Contuſions, Inflammations, Warts, Biting of it, *&c.* for theſe Diſorders eaſily ſpread through the cellular Membrane, and a Cancer itſelf follows, which often cannot be removed even by Extirpation.

§. 487. *Bellini* has demonſtrated by Experiments diligently and accurately made, that theſe Papillæ are the Organs to which the ſapid Object is applied in order to excite *Taſte* [1], to which the other Parts of the Mouth, Tongue, Fauces, and Palate, do not at all conduce; but perhaps thoſe Papillæ which are ſeated in that Part within-ſide the Cheeks, where the *grinding Teeth* [2] of each Jaw meet, may have ſome Share in the Taſte. The

1 The Taſte is no where perceived but in the Tip of the Tongue and Parts next adjacent. *Bellini* has made the Experiment upon himſelf with his Mouth open before a Looking-glaſs, as alſo upon another Friend being preſent. He dipped a Pencil-Bruſh in ſome ſtrong taſted Juice, as in that of Lemons, diſſolved Sugar, Sal Ammoniacum, *&c.* and applying them ſucceſſively to the Cheeks, Palate, Gums, and Root of the Tongue, no other Senſe aroſe from thence but that of Coldneſs or Moiſture. He then applied the ſame Bruſh to the Tip of the Tongue, and immediately there was always perceived a Senſe of Soureneſs, Sweetneſs, or Saltneſs to the Taſte. In the Root of the Tongue there is indeed ſome Degree of Taſte, but more dull. All theſe Experiments I have likewiſe repeated upon myſelf.

2 Ruminating Animals throw up a ſecond time into their Mouth the Food which they ſwallowed with little Maſtication. But that this ſecond Maſtication might not be without giving ſome Pleaſure to the Animal, Nature has placed guſtatory Papillæ within the Mouth near the grinding Teeth; which Papillæ appear like little Horns in the Cheeks of an Ox, or in the Head of a Sheep after boiling. But theſe have been alſo found by *Ruyſch* in the human Cheek after a happy Injection; for after taking off the Cuticle lining the Mouth, he found that there were nervous Papillæ ſeated near the Emiſſaries or Mouths of the ſalival Ducts, which are certainly in ſome meaſure Organs of Taſte, though more dull than thoſe of the Tongue. In the Palate there is no Taſte at all, notwithſtanding almoſt all People by an epidemical Error make it the Seat of that agreeable Senſe of taſting.

§. 488.

§. 488. That Matter in vegetable and animal Subſtances, from whence Art extracts Salt and Oil either ſeparately or mixed together, is the true Object or Matter of Taſte; which Matter therefore is either *Salt* [1], Soap, Oil, or Spirit; and the ſame is alſo true with reſpect to Foſſils.

[1] Earth and Water are inſipid, nor has Oil any Taſte but from ſome other Principle. For of itſelf Oil is ſweet or inſipid and ſmooth, if it is pure and not mixed with any foreign Matter. But the ſpirituous Rector which reſides in all Oils more or leſs, gives them ſome Taſte; but if that is removed, there is no manner of Taſte left in the Oil. But by the Name of ſpirituous Rector we here underſtand that moſt ſubtle Part of the Oil, or moſt attenuated Spirit, which is generally of a ſtrong or pleaſant Odour, and whoſe Force is immenſly great in proportion to its Bulk. This is eaſily demonſtrated in Wine, or even in Ale itſelf; for when theſe are lately drawn out from the Caſk, they are extremely pleaſant both to the Smell and Taſte; whereas by ſtanding expoſed to the Air but for the ſpace of a few Minutes, they loſe their Agreeableneſs, and become flat or dead without ſuffering any ſenſible Loſs in their Weight. That Part therefore which is the Principle of Taſte is indeed very ſmall, and generally reſides in the Salt and ſpirituous Rector reduced with the Oil into a Soap. *See our Chemiſtry*, Vol. I. p. 80.

§. 489. Taſte therefore is excited when the Object or Matter to be taſted (488.) is *attenuated* [1], and as uſually *diſſolved* [2] in the Saliva,

warmed [3] in the Mouth and applied to the Tongue by the Motion of the circumjacent Parts of the Mouth; and thus the ſapid Particles inſinuating through the Pores of the membranous Vaginæ, penetrate to the Surface of the nervous Papillæ which are lodged in theſe Vaginæ (485.), and which are thus affected, moved, and the impreſſed Motion conveyed from them to the common Senſory, where it excites an Idea in the Mind of *Saltneſs* [4], *Acidity* [5], *Alcaly* [6], *Sweetneſs* [7], *Vinoſity* [8], Spirituouſneſs, *Bitterneſs* [9], *Spicineſs* [10], Heat or *Pungency* [11], *Roughneſs* [12], or elſe a Taſte compounded of theſe.

[1] Hence the Pleaſantneſs of the Taſte is increaſed by Maſtication; and even ſapid Bodies themſelves have a leſs Taſte, if they are applied upon the Tongue quietly, without any Motion or Preſſure againſt the ſame.

[2] Salts taſte only when they are diſſolved, as *Bellini* obſerves, and the Tongue taſteth nothing, unleſs what has been ſo highly attenuated as to be capable of penetrating through the Pores of the external Coat of the Tongue to the Papillæ.

[3] Things which are extremely Cold are not taſted; nor can the Taſte be exerciſed where the Tongue itſelf is exquiſitely cold. Hence we read in the Travels of the Prince *de Radzivile*, that it was obſerved that every thing loſt its Taſte upon the Top of the Pike of the Mountain of *Teneriff*; nor did Spirit of Wine itſelf retain its Strength, but only the oily Wines of *Spain* and *Canary* preſerved their Strength uninjured.

[4] By this Name we underſtand the Taſte of Sea-ſalt, Sal-gem, or the Salt made from Springs, which

which Taſte we alſo call muriatic. But in a more general Senſe it may be taken to comprehend cryſtalline Salts of any kind, not excepting thoſe which are termed eſſential from Vegetables, as the Sal Acetoſæ, *&c.*

[5] Such an Acidity is taſted in Garden Fruits, in Wine, in Vinegar, Spirit of Sulphur, of Nitre and of Vitriol. For all theſe are Acids, however widely they may differ among themſelves.

[6] Alcaly may be particularly taſted in putrid Urine, and from thence Salts having ſuch a Taſte are termed urinous. Nor yet is there here an urinous Taſte in the Salts of the Urine naturally. For if recent Urine be diſtilled with a moderate Fire, it ſends over a mere Water; but if to the ſame Urine you add any fixed alcaline Salt, the Urine then continually exhales a volatile alcaline Salt. And in the ſame manner fixed alcaline Salts mixing with our Saliva in the Mouth, cauſe a Separation of a volatile alcaline Salt which gives an urinous Taſte.

[7] Of Sweets there are many Kinds, ſome taſting like Honey, others like Sugar, Manna, Caſſia, ripe Garden Fruits, or even Vinegar abſorbed into the Pores of corroded Lead, *&c.*

[8] There are perhaps a thouſand different taſted Wines, and as many Sorts of Ale, all which ariſe from the ſpirituous Rector mixed with an oily Acid; the Taſte of which latter is the ſame from whatever Vegetable it is produced, provided it is obtained pure and free from Mixture.

[9] Formerly they called the Taſte of Sea-ſalt alſo by the Name of bitter; but in our Times the Signification of the Term is altered, and we call thoſe Bitters which taſte like Wormwood, Aloes, Bile, Coloquintida, rancid Oils, *&c.* and ſuch a

bitter Taſte alſo ariſes from a Solution of Tin and Silver in Spirit of Nitre.

[10] We give the Name of Aromatic or Spicineſs to thoſe Vegetables, which by chewing feel hot to the Tongue and exhale a ſtrong Smell. Cinnamon the principal of Spices, and five hundred more of the aromatic Claſs, repreſent a particular Smell to the Mind when they are chewed in the Mouth, even though the Noſtrils are ſhut cloſe; and if the Smell of the ſame Aromatics is only received through the Noſe, they are alſo in ſome meaſure taſted at the ſame time. The ſame is alſo true with reſpect to the Smell of roaſted Fleſh, which being received by the Noſe of a hungry Perſon, makes the Impreſſion of its Taſte. Spices therefore ſeem to affect the Smell and Taſte at the ſame time; ſince being taken by the Mouth they fill the Noſe with their Odour, or their Smell being drawn through the Noſe alſo makes the Impreſſion of their Taſte in the Mouth.

[11] Pungent Subſtances as Euphorbium, Capſicum, Onions, Horſe-raddiſh, Muſtard, *&c.* are diſtinguiſhed from Aromatics, in their being deſtitute of an agreeable Smell.

[12] Roughneſs or Auſterity is remarkable in Galls, Oak, unripe Oranges, *&c.* where the Taſte is ſubacid and aſtringent in the Mouth.

§. 490. From hence it is very evident, how the ſame Object comes to produce different Taſtes in People under different *Ages* [1], *Conſtitutions* [2], *Diſeaſes* [3], or Cuſtoms and Sex? and why they often taſte of the thing which was before *applied* [4] to the Tongue?

Why

Why things of the ſtrongeſt Taſte, long continued are *painful* 5, as Salt, Spices, Spirits, *&c.* eſpecially when applied to the *naked* 6 Nerves, or to the Tongue after it has been excoriated?

Why things agreeable to the Taſte are alſo ſpeedy *Reſtoratives* 7?

And laſtly, why *Water* 8, ſoft *Oil* 9, and *Earth* 10 without Salt are inſipid? See §. 507.

1 The Smell of Rheniſh Wine when it is firſt poured out, does by its Acrimony cauſe the Noſe of the new-born Infant to contract and be much affected; whereas the Smell of the ſame is extremely pleaſant to an adult Perſon. Sugar and other ſweet things are moſt agreeable to Children, but in People who are advanced in Years, they ſeem to be too clogging and weak: but on the contrary things that are Salt, acrid or ſpirituous, diſpleaſe Children, and are very agreeable to adult People; namely, becauſe in tender Children, the guſtatory Nerves are very ſenſible and tender, ſo that they can bear only things which are of a mild Taſte, being too violently affected by ſuch as are acrid: whereas the Nerves of adult People being more callous, are not ſufficiently moved by thoſe weak and mild Subſtances, but only by ſuch as are ſtrong and more pungent.

2 Sweets are of pernicious Conſequence to hyſterical Women; and no wonder, ſince the Nerves of the Teeth being uncovered from their vitrious Cruſt, are by nothing more injured than by Sugar, which increaſes the Pain beyond any thing, even to Convulſions; and for the ſame Reaſon Sweets are prejudicial in the Tooth-ach.

[3] From Diſeaſes ariſe ſurpriſing Corruptions of the Taſte. In chlorotic Girls almoſt all Taſtes are aboliſhed; and therefore they are pleaſed with things that are acrid and ſowre, capable of penetrating the redundant Mucus of the Stomach. In thoſe who have the Jaundice, the Bile is depoſited together with the Saliva into the Mouth, whence every thing ſeems to taſte bitter, though there is not any Fault in the Food. In leucophlegmatic People there is often an intolerable nauſeous Sweetneſs in the Mouth, almoſt like that of Saccharum Saturni, which is extremely troubleſome and ſometimes fatal: whereas the Perception of a ſalt Taſte in the Mouth of thoſe afflicted with the Plague, is a moſt certain Sign of Health or Recovery. Thus I have been informed, by ſome of my Friends of great Credit, from *Aſia*; that in putrid Diſeaſes the Patient is very deſirous of Acids to the great Benefit of Nature; and in the ſame Diſorders we abhor Alcalies and covet Acids.

[4] Only the Order of taking different Kinds of Food the one after the other, may either add to or greatly diminiſh the Agreeableneſs of their Taſte. After muriatic Salts an acid and watery Wine is the moſt agreeable; whereas the ſame will be diſpleaſing if drank after any thing that contains Honey or Sugar. Some of the Remains of the former ſapid Body ſeem to lodge themſelves for a time in the Pores of the membranous Vaginæ which cover the Papillæ, until they are expelled and excluded or elſe amicably mixt with the Particles of the ſapid Body, which is laſt taken into the Mouth.

[5] It is a remarkable Obſervation in *Malpighi*, that a certain *Italian*, named *Corbetta*, had the external Covering of the Tongue ſo thin that it was almoſt naked. In this unfortunate Perſon all Sorts

of

of Food which were taken excited Pain, inſtead of an agreeable Taſte; ſo that none but a Diet of Milk, Fleſh-broths or Water could be uſed without Torment. Thus a Tongue which has been ſcalded by Water or burnt by Fire, is not capable of Taſting. It was therefore neceſſary for a kind of Mucus and Vaginæ or Covering, to be interpoſed betwixt the ſenſible Papillæ and the ſapid Object to moderate the Senſe; nor does Taſting ſeem capable of being performed, if the Tongue is deſtitute of theſe Mediums.

[6] The moſt pleaſant Wine applied to the naked Nerves, as for Inſtance, in the Eyes, excites Pain and Tears: and almoſt the ſame Effects will it produce in the Noſe and upon the Tongue of a tender Infant, when at the ſame time nothing ſeems more agreeable to the Tongue of an adult Perſon.

[7] The moſt ſapid Bodies are thus inſtantly reſtorative, inaſmuch as they contain a great deal of the powerful ſpirituous Rector, which alone gives Taſte to inſipid Bodies, and is ſo ſubtle a Liquor that *Sendivogius* eſtimates it to be but $\frac{1}{8100}$ Part of the whole Body. Thus from a whole Pound of Cinnamon there are ſcarce ſixty Drops of Oil diſtilled, and thoſe ſixty Drops being diminiſhed but one Grain in Weight, by expoſing to the Air, have no Taſte. Yet ſo ſmall a Weight or Portion of that ſingle Grain as is diffuſed through each Drop of the Oil, is capable of being abſorbed by the ſmalleſt Veins, and extending to the Blood without loſing its Efficacy ſo as to recruit and invigorate the whole Body. (See §. 67.)

[8] Water, becauſe it does not affect our Senſes, if it is weaker than that Moiſture which continually ſupplies the ſenſitive Organ. Thus we do not perceive the Pulſation of the Heart and Arteries

while we are well, but we are only ſenſible of it when they vibrate with too great Violence. Hence pure Water ſeems to be deſtitute of Taſte, becauſe it is leſs ſalt than our Saliva; but the Taſte of the Saliva never leaves the Tongue, and upon that account it is not perceived. But when once Water begins to have a Taſte, it is no longer pure. Things unaccuſtomed in general affect the Senſes ſo much the more ſtrongly, in proportion as the Objects were uſed to be more violent. There was a certain *Engliſh* Gentleman who by Misfortune was condemned to a ſubterraneous Priſon deſtitute of all the uſual Light: for the firſt he could not at all diſtinguiſh any Object, but afterwards to his Surprize he began to ſee the Walls, at length he could diſtinguiſh his Skin, and at laſt diſcern Letters ſo as to be able to read. From whence it is ſufficiently manifeſt, that the weak Rays of Light now became ſenſible to the Eye, which being before more callous neglected thoſe faint lucid Rays. Another Inſtance is related by Mr. *Boyle*, of a Man who was blind from his Birth, and who being couched for a Cataract when he was come to adult Age, did from the unuſual and ſudden ruſhing of the Light into his Eyes, perceive a kind of Pleaſure and Itching throughout his whole Body, like that in the Act of Venery, with ſo great a Commotion that he fainted away; which Tenderneſs of Sight however vaniſhed by Degrees, as he grew more accuſtomed to the Light. *Dionyſius* being well aware of this Experiment, in order to torture his Enemies more exquiſitely, uſed to expoſe them ſuddenly to the ſtrong Light of the Noon Sun, by opening their Eyelids after they had been kept for a long time in Darkneſs.

9 Freſh Butter well waſhed in Water is inſipid. There is a wonderful Proceſs in *Iſaacus Hollandus*, by

by which a mild and innocent Oil is obtained from human Blood: namely, he diſtills by a ſtrong Fire that very acrid, ill-taſted and ſmelling empyreumatic Oil, and that Oil he prepares in a Veſſel, beating it Day and Night with Water, altogether in the ſame Manner as in making Butter; whence all the Saltneſs went into the Water, and the Oil continued mild, white and inſipid like that of Wax. The great Labour did not deter me from trying the Experiment, which I found to be true.

[10] Becauſe Earth conſiſts of ſuch groſs Particles that they cannot paſs through the Pores of the nervous Vaginæ, and by that means remain capable of affecting the ſubjacent Papillæ.

Of the SMELLING.

§. 491. THE broad Noſtrils tending upwards from a larger Capacity to a *leſs* [2], and being *double* [3] or one on each Side, are extremely well adapted to *draw in* [4] the volatile and odoriferous Particles together with the Air, ſo as to convey and apply them to the Surface of their Membranes; and this more eſpecially when the Alæ are drawn outward below or *contracted* [5] above by the united Action of the Conſtrictores Alarum Naſi, which ariſe fleſhy from the anterior and lower Part of the fourth Bone of the upper Jaw, and are inſerted obliquely within the Alæ Narium, ſometimes together with the ſemilunar Muſcle of *Euſtachius*.

The

[1] The Smelling approaches near to the Seat of Life and of the Mind. Nothing recruits the Strength ſo ſuddenly and powerfully as a ſpirituous Medicine drawn up the Noſe: Fainting or Swoonings in hyſteric Fits are by nothing ſo ſoon removed as by Medicines drawn through the Noſe. Nor does any thing ſo ſoon excite Diſeaſes as a ſpirituous and virulent Matter of a Nature foreign to our Bodies.

[2] The Noſtrils contract or grow ſmaller upward, and diminiſh in ſuch a Manner that at their Termination in the Region above the Palate, their Opening is ſcarce thicker than one's Nail. Hence it happens that they may be eaſily cloſed, and, like a converging or conical Tube growing narrower, affect the Nerves with a ſtronger Senſe of Smelling. Hence it happens that when the pituitary Membrane is ſwelled as it frequently is in a Cold, the continual Paſſage of the Air through the Noſtrils is then intercepted, the Smelling ceaſes, and the Breath of the Perſon ſleeping can be only drawn through the Mouth. This Narrowneſs of the Paſſage through the Noſtrils is a Caution of Nature to prevent volatile Inſects, Duſt, Poiſons, *&c.* from being drawn through the open Noſtrils into the Lungs, ſo as to ſuffocate the unwary Animal; for thus they are either repelled by the Narrowneſs of the Paſſages, or elſe they are reſiſted by the oppoſite Mucus or Hairs, 'till at length they are caſt out by the Force of Sneezing.

[3] The anterior Part of the Noſe is formed with a Cartilage that it might eaſily bend without breaking. But the Cartilages are covered with the ſame olfactory Membrane as inveſts the Bones of the Noſe.

[4] When the Ribs are elevated and the Cavity of the Thorax dilated, the Air filled with odorous Particles

Particles ruſhes violently through the Noſe into the Cavity of the Lungs, in which there is made an imperfect Vacuum. But that the Thorax is a Machine adapted to form a Vacuum is eaſily demonſtrable. For thus the moſt ſtrong ſmelling Bodies are excluded from our Senſation when we hold our Breath, nor can even the Smell of Spiritus Salis Ammoniaci itſelf affect the Noſe but when the Air is inſpired or drawn into the Lungs.

[5] For in that State by the Force of the inſpired Air, and the Force of the conſtrictor Muſcles of *Euſtachius*, the odoriferous Particles are applied to the ſenſible Membranes of the Noſe. We uſe this organical Action of the Muſcles, when we endeavour to accurately diſtinguiſh any faint Smell.

§. 492. But the Cavity of the external and internal Noſe includes all that Space into which open, 1. The *frontal Sinus*'s which are generally formed betwixt the two Tables of the Os Frontis, removed from each other under a Protuberance beneath the Eye-lids, from whence they open by a Foramen above into the Cavity of the Noſtrils, near the upper Part of the Oſſa Naſi; they are lined internally with a mucous Membrane of the Noſe, which is ſpread all over the internal Surface of their Cavities, where the Mucus being formed, diſtills from thence into the Cavity of the Noſe. 2. The Antra Higmoriana, which are large and ſeated in the upper Jaw opening with a large Aperture into the Cavities of the Noſtrils; and theſe likewiſe receive the ſame Membrane, and ſerve to ſeparate, collect and diſcharge

diſcharge the Mucus into the Cavity of the Noſe. 3. The ſmall Cells of the Os Cuneiforme under the Os Spongioſum, opening by ſeveral diſtinct Perforations into the Cavity of the Noſtrils; which Cells alſo receive the mucous Membrane of the Noſe, which lining them ſeparates, and that way diſcharges the Mucus.

1 Theſe frontal Sinus's are found very large when the Smelling is more perfect than uſual. In hunting Dogs they are very ſmall, but very large in Setters, or thoſe which take the Scent. In thoſe who have their Noſe very flat or depreſſed, and the frontal Sinus's abſent, in them the Senſe of Smelling is either abſent or leſs than uſual. Nor are theſe Sinus's to be found in the Fœtus. For all the Organs of Senſe lie idle in the unborn Infant, and are defended from all the Impreſſions of external Objects. The Ear is cloſed or ſtopped up, that the Infant may not be ſtartled by any violent Sound, the Humours of the Eyes are turbid or opake, inſomuch that one would imagine that new-born Infants were blind if the Humours did not recover their Clearneſs and limpid State in a few Days time; and this Opacity of the Humours in the Eyes of young Brutes is ſtill greater. In the ſame manner alſo Nature has not given the Fœtus any of the pituitary Sinus's, that it might be ſenſible of Smells. But when as Age advances, the Diploe is augmented betwixt the Tables of the Cranium, theſe Sinus's are then left betwixt them. And in the ſame manner as Age advances, and the Head grows larger, the maxillary Sinus's are formed. It is the Abſence of theſe Sinus's which occaſions the Noſes of young Children to be perpetually running with Mucus; for they are the Receptacles of the Mucus, with which

which being filled, it is afterwards returned from them or regurgitated from the Antra. Theſe Cavities are larger in the Adult, and are capable of holding almoſt an Ounce of Liquor: they are not therefore formed by Nature to no Purpoſe, but with a View of increaſing the Surface of the pituitary Membrane, for the more perfect Performance of the Smelling; and I am very apt to believe, that if this Membrane could be taken out from all thoſe Cavities uninjured, it would appear twenty times as large as the external Noſe.

§. 493. Beſides theſe, in the Cavity of the Noſtrils are concealed and artificially diſpoſed in different Parts four ſmall ſpongy Bones called the *Oſſa Spongioſa* [1] of the Noſe, two in each Noſtril or Cavity of the internal Noſe; the one of theſe two Pair of ſpongy Bones is connected above and before to the upper Part of the Jaw-bone, where it unites to the Apophyſis of the Os Frontis, at the internal Angle of the Eye; the other is faſtened in the lower Part of the Cavity of the Noſe to the upper Jaw-bone itſelf. Theſe four ſmall Bones are wonderfully framed of very thin Plates or Lamellæ thinner than Paper, but ſo convoluted or folded up together that they form a great many hollow Cavities, within which the pituitary Membrane inſinuates itſelf, ſo as to paſs in and out from thoſe little Caverns, and accurately inveſt the whole Surface betwixt the Lamellæ, and leave a free Space or open Cavity betwixt them. The Cavities of theſe thin Bones and of all their ſmaller Cells, have a free

a free and open Communication into the Cavity of the Noſe.

[1] The Oſſa Spongioſa are accurately placed againſt that Part of the Noſtrils where they are narroweſt. But they are compoſed of Leaves folded together as thin as Paper, more eſpecially in Animals of exquiſite Smell; and in ſome Animals where this Bone takes the Name of Turbinatum from its many Convolutions, there are at leaſt thirty Lamellæ, each of which are covered with their olfactory Membrane, which may be beſt freed from the Bone in order to prepare and preſerve it by placing it in a Box full of Holes in the midſt of an Ant-hill. Thus there are ſixty plain Sides or Surfaces of this Membrane, each equal to its bony Lamellæ. But it is manifeſt by theſe Means the Senſe of Smelling becomes greatly increaſed, though it would be otherwiſe dull.

§. 494. The external and internal Noſe compoſed of Bones, Cartilages and Membranes, are inveſted or lined with a *thick* [1] and ſoft mucous Membrane, adorned with Myriads of ſmall arterial *Veſſels* [2], and furniſhed with round glandular *Corpuſcles* [3] together with very ſmall Veſſels which diſtil a *thin* [4] Lymph into the Cavity of the Noſtrils; and under that Membrane is ſpread the Perioſteum and Perichondrium, which is a very thin nervous and vaſcular Membrane. Both theſe Membranes conjoining ſtrictly together, inſinuate themſelves into the Cavities of the ſix Sinus's beforementioned (§. 492.), and into the Cells of the four Oſſa Spongioſa (§. 493.): ſo that by a wonder-

wonderful Contrivance, this Membrane is expanded into a very large Surface, within the narrow Compaſs of the Cavity of the internal Noſe; but they are diſpoſed ſo as not to hinder the Uſe of each other.

[1] Its Thickneſs ariſes in a great meaſure from the many Cryptæ and large Quantity of Mucus; for of itſelf this Membrane is ſo thin that it ſcarce equals the tenth Part of the Thickneſs of a Sheet of Paper.

[2] *Ruyſch* having injected Wax by the crural Artery in a Fœtus with great Artifice, found that the injected Matter eſcaped through the Noſe, in the ſame Manner as if it had bled, which is a manifeſt Sign that the Arteries open themſelves in this Part; and therefore it is no wonder that by violently blowing the Noſe, Blood ſhould be ſometimes forced out. In Oxen, Sheep and other Animals who have a long Noſe continued from their Eyes forward, in order for them to more accurately diſtinguiſh poiſonous from ſalutary Herbs by the Senſe of Smell; in ſuch Animals theſe muciferous Arteries run forward in a Parallel Courſe, and diſcharge a lymphatic Juice with which the whole Membrane is moiſtened: but theſe excretory Ducts being obſtructed the Arteries ſwell, the Noſtrils are ſtopped up and the Smelling ceaſes, as we obſerve in the Diſorder which we call a Cold.

[3] Such glandular Corpuſcles are admitted even by *Ruyſch*, though he calls them by a ſomewhat different Name, to wit Cryptæ. In a healthy Perſon who has lately expired by a violent Death, upon opening the Head and preſſing the Membrane of the Noſe, it diſcharges a pellucid Liquor readily congealing into Scales, which ſeems to iſſue from

from many ſmall ſpherical Points. With ſuch a pellucid Humour or one not much different, the Eyes themſelves are moiſtened, which Humour ſoon congeals into a white Liniment if it is not wiped off. With the Mucus of theſe Glands the tender Nerves are defended.

[4] The Mucus ſoon after Secretion is not thick or like a Liniment, but becomes of that Conſiſtence by ſtanding in the Cryptæ or Cells of the Membrane; and at length only by ſtanding or exhaling its more watery Part by Fire it concretes into hard and tough Scales. When it becomes inconvenient or uneaſy by ſtanding too long in the Noſe, or being collected in too large a Quantity, it is then uſually diſcharged by Sneezing; and hence it is that healthy People uſually diſcharge the accumulated Mucus by Sneezing as ſoon as they riſe in the Morning. But in old People and in Children the Heat does not ſo much diſſipate the thinner Parts of this Mucus, and therefore in the Winter-time they have a Dripping at the Noſe.

§. 495. The olfactory Nerves paſſing *without* [1] the Dura Mater to the Os Ethnoides, tranſmit their tender Fibres through the ſmall *Foramina* [2] which we obſerve in that Bone, and which are lined with Productions of the Dura Mater; through theſe Foramina the nervous Fibres paſs out of the Os Cribriformæ and are immediately diſtributed throughout the large Surface of the Oſſa Spongioſa (§. 494.) into all the Sinus's and Cells (§. 492, 493.) in an accurate Manner.

That

[1] That is, the ſoft pulpy Subſtance of the Brain itſelf being continued to the Os Cribriforme, paſſes through the Foramina of the ſame Bone, which are inveſted with the Dura Mater, into the Noſe, where they are expanded in the Form of a Membrane; ſo that within our Noſes the naked Subſtance of the Brain itſelf lies expoſed. This is the Reaſon why the Ancients would not venture to give them the Name of Nerves, but called them mammillary Proceſſes. In brute Animals even the Ventricles of the Brain itſelf continue their Cavities forward with the olfactory Nerves into the Noſe, in ſuch a manner that one may inflate them like Tubes, and even diſtend the whole Brain itſelf by blowing through them. For in theſe Creatures Nature has furniſhed them with nothing more than an exquiſite Senſe of Smelling, in order to chuſe out their Food. If a thouſand different Herbs are given to an Ox or a Sheep in an Armful of Graſs, they will by their Noſes diſtinguiſh and pick out from all the reſt, that which may be taken as Food without Injury.

[2] Theſe Foramina are apparent enough in the Skeleton, but in the recent Body they are almoſt quite cloſed up: for the Dura Mater fills every one of theſe Foramina, and is continued through them like a Funnel; each of theſe little Funnels being filled with its proper Branch of the olfactory Nerves, which are a Continuation of the Brain itſelf. But by the Interpoſition of the Proceſſus Criſta Galli the ſoft olfactory Nerve is defended from being injured by the incumbent Maſs of the Brain.

§. 496. From hence it appears that the Expanſion of theſe Nerves is very *large* [1]; nor are there any Nerves throughout the whole

Body ſo *ſoft* [2] and naked, and therefore they are more apt to be eaſily affected and injured in this Organ of Senſation.

[1] The optic Nerve is expanded into the Retina, and the auditory Nerve into the Membrane of the Labyrinth, the guſtatory Nerve into the Tip and Part of the Side of the Tongue; but the olfactory Nerve has an Expanſion even as large as that of the pituitary Membrane itſelf of *Schneiderus*.

[2] There are many Properties or Affections of Bodies, which are no way diſcoverable but by the Senſe of ſmelling. Sugar is pleaſant to the Taſte, does not injure the Eyes, nor any other of the Senſes; but the ſame being applied to the naked Nerve of the firſt Pair for ſmelling, or being applied to the naked Nerve of a Tooth, excites ſo ſevere a Pain, as almoſt occaſions Convulſions. As theſe Nerves are ſo tender in their Expanſion, it was neceſſary for them to be well defended from external Injuries, leſt they ſhould be ſoon deſtroyed by Attrition, or become inſenſible by contracting a Calloſity. It is well known how ſmall a Force will deſtroy the Senſe of ſmelling; as, for Inſtance, by walking againſt the Wind, *&c.*

§. 497. Therefore in all the numerous *Glands* [1] of this Membrane, as alſo from the numerous arterial Veſſels, which are ſo plentifully diſtributed in little Faſciculi or Bundles, there is continually ſeparated and diſcharged a ſoft or inſipid Fluid and inodorous Humour, almoſt without Colour or the leaſt Brackiſhneſs, which lubricates, moiſtens, and defends the Nerves (§. 496.) on all Sides, and in all their

their Expanſions throughout the ſeveral Cavities before deſcribed (§. 492.) This ſame Humour ſtagnating without Motion, and collected in a warm Place, through which the Air freely paſſes, becomes continually *thicker* [2], and is diſcharged under the Name of Mucus in all Poſtures of the Body; the Uſe of which Mucus is to preſerve theſe very tender and naked Nerves in their natural and ſound State for many Years, which could not be effected otherwiſe.

[1] To preſerve theſe Nerves ſenſible, and at the ſame time defend them from being too eaſily injured, Nature has uſed a twofold Precaution: 1. By continually diſtilling a thin limpid Humour by ſmall Veſſels continued like a Navel from each of the numerous Cryptæ; which Humour being inſipid in healthy People, is yet brackiſh in Diſorders, and in thoſe who have a Running at the Noſe; and being diffuſed throughout the whole pituitary Membrane, it often thickens like a Liniment. 2. By a limpid Humour like the former, inſipid or but very little brackiſh, which diſtils immediately from the open Ducts of the parallel Arteries, diſtributed through the Membrane of *Schneiderus*, without the Intervention of any Cryptæ or Cells; ſo that meeting with no Confinement, it is diſcharged quite thin and watery. Theſe exhaling Arteries have been demonſtrated by *Ruyſch*, by a Method which is not difficult to imitate. Let one of the carotid and both of the vertebral Arteries be tied in ſome Animal, and inject Water by the other carotid, and the Liquor will immediately diſtil through the Noſe. This Liquor appears to continually diſcharge itſelf

while the Animal lives; for if you carefully dry up the Mucus of the Noſe, it will in a little time after appear moiſtened again with the ſame. It is from theſe laſt Ducts continued immediately from the Arteries, that Blood is ſo eaſily diſcharged at the Noſe by any violent Irritation.

[2] Namely, the ſame liquid Mucus retained in the Sinus's of the Os Frontis, Sphenoides, and upper Jaw, becomes inſpiſſated into a thicker Mucus, which is conveyed into the Noſe by different Poſtures of Body according as the Sinus's themſelves are ſituated. It diſcharges itſelf from the left maxillary Sinus, when a Perſon lies with his Head on the right Side, and the Reverſe; from the frontal Sinus it diſtils while the Head is retained in a perpendicular Poſture, and from the Sinus ſphenoidalis when the Head is inclined forward. Thus the Mucus diſtilling from all theſe Sinus's, defends all the naked Nerves, and preſerves them from too great Irritation, in the ſame manner as Pictures are covered over with a Varniſh made of the White of an Egg, to preſerve the Colours from being altered by the Air. The Name of an Excrement is therefore very improperly given to ſo uſeful a Liquor.

§. 498. But leſt this Humour ſhould ſtagnate too long in its Cavities, ſo as to thicken and change into a *tophous* [1] Matter, incapable of being afterwards diſcharged by the narrow Paſſages of thoſe Receptacles; therefore a Branch of the Nerve of the *fifth Pair* [2] uniting with the Nerve of the ſixth Pair, is diſtributed throughout the ſame Membrane; and theſe being irritated, affect the Par vagum and intercoſtal Nerves, ſubſervient to the Muſcles

Muſcles of the Reſpiration, whence the Mucus is *abſterged* 3 and forcibly expelled by the Impulſe of the Air, violently forced through the Noſe in *ſneezing* 4.

[1] This Mucus when dried, readily concretes into Scales, and afterwards hardens into a chalky Matter, more eſpecially when the inſpired Air is very dry and full of Duſt. But this Mucus alſo hardens into a ſcaly Subſtance, when it has been taken out of the Body, and dried in a clean Glaſs. From theſe Cauſes may ariſe that troubleſome Diſorder in the pituitary Sinus's, which we call a Polypus in the Noſe; for there is no other true Cauſe of this Diſorder, ſo frequent as this before-mentioned, namely, ſuch an Inſpiſſation of the Mucus, that it cannot be evacuated; whence it happens that new Mucus being continually accumulated while nothing is diſcharged, the whole Sinus is at length filled, the Cryptæ and Membranes of the Veſſels are obſtructed, and by that means the latter is diſtended ſo as to protrude itſelf into the Cavity of the Noſtrils, and intercept the Paſſage of the Air, ſo that it might be often ſeen pendulous in the Fauces like a Lump of Fleſh. This Mucus being alſo corrupted, produces an Ulcer termed an Ozæna, which corrodes the adjacent Bones.

[2] This Nerve ſends off a large Branch from the Cavity of the Orbit to the Noſe, where it is diſtributed throughout the whole Membrane of *Schneiderus*, however largely that is expanded in the Noſe. Theſe Nerves of the fifth Pair are very naked and eaſily irritated, ſince by touching them only with Sugar they excite ſneezing, which is a convulſive Motion. Even in the Apoplexy itſelf,

when the Body lies like a dead Trunk without Senſe and Motion, ſneezing may be excited only by irritating the Noſe with a Feather. Every thing therefore which irritates or injures theſe Nerves, will continually vellicate the communicating Nerves of the eighth Pair with the Intercoſtals and Recurrents; whence the Diaphragm, Abdomen, and all the Organs of Reſpiration will be ſuddenly contracted, and expel the Air from the Lungs with a great Force. From this Torrent of Air ruſhing through the Noſe and into the Sinus's, ariſes that uneaſy Senſation, which is excited in the ſenſible Membrane of the Noſe at the time of ſneezing, which is performed after the Manner next deſcribed.

[4] Namely, by retaining as large a Quantity of Air as poſſible, and then by ſuddenly diſcharging the ſame with a conſiderable Force, with a ſort of convulſive Motion throughout almoſt all the Muſcles in the Body. The Uſe of this Action is to cleanſe the Organs of ſmelling. It commonly happens in a Morning as ſoon as we riſe; for the Mucus which has been collected all Night without being evacuated, fills the Sinus's, and loads the Membrane ſo much, that in a Morning our Senſe of ſmelling is either much diminiſhed, or quite aboliſhed. At that time therefore ſneezing is more frequently performed by the Conſent or good Advice of Nature, for the Benefit of the whole Machine: Hence Water is firſt diſcharged, and ſoon after the Mucus itſelf which adheres to the Sides of the Membranes, ſo as to facilitate the Reſpiration and recover the Senſe of ſmelling, or render it more exquiſite. Phyſic, in Imitation of Nature, has found nothing more ſerviceable for an inveterate Stoppage of the Noſe, or an incipient

Polypus,

Polypus, than the ſnuffing up of warm Water, and expelling it afterwards by ſneezing.

[3] When we expoſe ourſelves to the cold Air of an Evening and ſneeze, we underſtand that the next Day we ſhall be troubled with a Cold, or a Stoppage of the Noſe. They who are afflicted with an ardent Fever, and ſneeze towards the latter End of the third Day, generally eſcape from the Diſeaſe.

§. 499. But ſuch *Parts* [1] of animal, vegetable and mineral Subſtances become the Object of ſmelling, as are *ſpirituous* [2], oily, ſaline, or ſaponaceous, and ſo attenuated or divided, that they are capable of floating in the Air: but it is evident from numerous Experiments, that the *ſubtle* [3] Matter which we call Spirit, reſiding in the Oil, is more eſpecially that which excites the Smell; for that being perfectly *ſeparated* [4] from odorous Bodies, what remains has little or no Smell, and the ſame Matter being poured upon other Subſtances communicates a Smell to them.

[1] Such are Oils converted into Spirit by Fermentation, as in Vinegar and Spirit of Wine, the volatile alcaline Salts of Animals, mineral, acid and ſulphureous Spirits, except Oil of Vitriol, which is inodorous.

[2] The Name of Spirit is given by the Chemiſts to that ſubtle Matter lodged in the Oil, ſalt and ſaponaceous Part of foſſil, animal and vegetable Subſtances, which is ſo volatile as to fly off ſpontaneouſly from the Oil and Salt, and affect the Noſe; and this is the only Matter of Odours: for an odorous Body, whether pleaſing or diſpleaſing,

ſing, has no longer any Smell when once it is deprived of its ſpirituous, oily and volatile ſaline Parts. Nor does the fixed Salt or the Water, nor even the Oil itſelf, contain any Smell when deprived of this Spirit. Alſo the volatile alcaline Salt has not any Smell but from this ſpirituous Rector; which is therefore the true Object or Matter of Smells. But the oily Parts are in ſome meaſure ſubſervient to this Senſe, ſince they fly off together with the ſpirituous Rector, and adhering to the Surface of the olfactory Membrane, render the Effect or Action of the odoriferous Particles more permanent and laſting.

[3] This is ſo ſubtle, that it even eſcapes the Imagination. A Roſe fills a whole Chamber with its moſt fragrant Smell; whereas if the ſame be bruiſed betwixt the Fingers, it ſmells watery and diſagreeable; nor yet will it retain any thing of its Smell, if it lies by for the ſpace of twenty-four Hours. The ſame Roſe being committed to Diſtillation in a cloſe Veſſel, affords ſo ſmall a Quantity of an Oil, that from a hundred Pounds of Roſes, ſcarce a few Drops of the precious Oil is obtained, which muſt be at leaſt ten times more valuable than Gold. Laſtly, this ſo dear and ſcarce Oil becomes itſelf inodorous, only by exhaling an inſenſible Portion or Weight of its ſpirituous Rector, as we ſaid before concerning the Oil of Cinnamon.

[4] So ſoon as that volatile and very ſubtle Spirit is removed from the odorous Body, all that then remains is more groſs, and rather excites Pain and Sneezing than an agreeable Smell.

§. 500. If the Aſpera arteria or Windpipe be divided, and the Animal breathes through the

the open Wound, there will be *no* [1] Smell perceived even from the ſtrongeſt Objects.

[1] Take two Dogs, and in the one, after dividing the Skin, make an opening by Inciſion into the Trachea or Wind-pipe, and the Lips of the Wound being dilated or drawn from each other, all the Paſſage of the Air through the Noſe and Mouth will then ceaſe, and the Animal will perſpire only through the lower Part of the Wind-pipe. If now Spirit of Sal Armoniac made with quick Lime be held to the Noſe of ſuch a quick ſmelling Animal, he will afford no Signs of perceiving any ſuch Smell; but if the ſame Spirit be applied to the Noſe of another Dog, it will excite Convuſions in a ſurpriſing manner.

§. 501. When the Air is *expelled* [1] from the Lungs through the Noſtrils, there is no Smell of any external Object perceived.

§. 502. Nor is any Smell perceived while the Breath is held.

[1] The ſame Spirit of Sal Armoniac being applied to the Noſe, will not at all affect us, ſo long as we either only breathe out the Air, or do not draw it into the Lungs through the Noſe. When we walk through a ſtinking Place, there is not a better Remedy to avoid the diſpleaſing Smell, than that of holding the Breath. The Smell therefore of any thing cannot be perceived, unleſs the Air by its Weight ruſhes into the dilated Lungs, by the imperfect Vacuum made by the Muſcles which dilate the Thorax, and at the ſame time carries with itſelf the Effluvia through the Noſe, which it receives from the odoriferous Body.

§. 503. For the Smelling is performed at the time when the Breath is drawn through the Noſtrils.

§. 504. And the *ſtronger* [1] and more frequent the Reſpiration is made, the more powerfully is the Organ of Smelling affected.

[1] The quick-ſcented Hound in chaſing any Animal by the Scent, applies only his Noſe to the Ground, and by a ſwift Motion of the Ribs breathing alternately, ſuddenly diſtends his Lungs with Air like a Pair of Bellows, and expels the ſame again. By this means the Air is indeed drawn by repeated Inſpirations through the Noſe without being admitted into the Lungs, by reaſon of the Expiration which immediately follows; and thus being admitted only to the Noſe, conveys all the odorous Effluvia, which it contains, to the Organ of Smelling.

§. 505. The Smell of odoriferous Objects is increaſed by *Motion* [1], Heat, Attrition, and *Mixture* [2] of different Bodies; as alſo by a careful Mixture of Salts, with odorous Oils [3].

[1] Some Bodies only emit a grateful Smell by Warmth and Attrition, as Amber, Lignum Aloes, *&c.*

[2] For by Mixture of Sal Ammoniacum with an alcaline Salt, both of which are of themſelves inodorous, they nevertheleſs at the Inſtant of mixing exhale a moſt intenſe Smell. If Salt of Tartar be applied to the Noſe, at the Inſtant when it is taken out of the Fire, it has no Smell; but if you breathe upon it, it immediately exhales the Smell of

of an Alcaly. If a Grain of fixed Salt be taken into the Mouth, it gives the Taſte of burning without affording any Smell; but ſo ſoon as it mixes with our Saliva, it affords an urinous or fœtid Smell; inaſmuch as the fixed Salt of Tartar combines with the Acid of the Saliva, and ſets at liberty the volatile Alcaly, which exhales and diſcharges itſelf by that Means.

[3] The aromatic and fragrant Odours of Bodies mixed with Acids, as for Inſtance, with the Juice of Citrons, increaſe their odorous Virtue, whereas by mixing with Alcalies their Smell is diminiſhed. The *Italians* who are moſt famous and curious in Perfumes always uſe mild Acids, as for Inſtance, in preparing their Gloves which always ſmell of ſomething acid together with Ambergreaſe.

§. 506. The Senſe of Smelling is therefore performed while the odorous Effluvia contained in the Air, are by the Motion of Inſpiration and the Figure of the Noſe, with the Poſition of the ſpongy Bones ſo ſtrongly impreſſed or applied to the ſmall Fibres of the olfactory Nerves, that by their Action an Idea is communicated and excited in the common Senſory, either of an *acid* [1], alcaline, aromatic, putrid, *vinous* [2], or other more compound Odor.

[1] The Fumes of Vinegar excite a Senſe of Acidity in the Noſe, and likewiſe communicate the ſame kind of Taſte to the Tongue; for an Acid is perceived by the Organs of Smelling if it is volatile, otherwiſe it is only ſenſible to the Taſte. Thus Oil of Vitriol while cold does not affect the Noſe, but is only ſenſible to the Tongue; but when

when attenuated and rendered volatile by Fire, it ſmells violently acid.

[2] All Sorts of Ale, Wine, and Liquors prepared by Fermentation, from whence inflammable Spirits are diſtilled, afford this vinous Smell.

[3] Innumerable are the other Sorts of Smells which are hardly reducible to any Claſſes, as Ambergreaſe, *&c.*

§. 507. From hence we may be able to underſtand, the great Affinity or Relation there is betwixt Smells and *Taſtes* [1], or betwixt the Objects of Taſting and Smelling?

Why Smells frequently reſtore a Perſon to *Life* [2] in a Moment?

By what *Means* [3] *Diſeaſes* [4] and *Death* [5], with almoſt every kind of Operation proper to Medicines and Poiſons, are ſometimes produced by Smells? how the ſame Smell in *different* [6] People comes to produce different and even oppoſite Effects?

Why Animals which have a *very long* [7] Beak or Noſe, with very large Oſſa Spongioſa, as *Birds* [8], have a more exquiſite Senſe of Smelling?

What are the very minute *exhaling* [9] Corpuſcles, which are capable of exciting a copious and ſtrong Smell for ſo long a time without any ſenſible Diminution in the Weight of the Object or Body?

By what means a *fætid Smell* [10] exhaling from the putrefied Parts of Animals and Vegetables ſo obſtinately adheres and excites a diſagreeable Senſe in the Noſe for a long time after it has been perceived? Whe-

Whether the ſtrongeſt Smells are not *Sternutatories* [11]?

Of what *Uſe* [12] is the Humour and Mucus which is continually formed and diſtributed throughout the Membranes of the Noſe?

Why the Senſe of Smelling is *dull* [13] as ſoon as a Perſon awakes, but becomes more *acute* [14] after Sneezing?

Whether this mucous Humour ſerves to purge the *Brain* [15]? and how far that is true?

Whether or no the Mucus is thick at its firſt Formation? or whether it becomes ſo afterwards?

From whence ariſes the intimate Conſent or *Communication* [16] betwixt the internal Noſe and Muſcles of Reſpiration, together with the abdominal Viſcera?

Whether Sneezing is not a Convulſion, and upon that Account ſo tireſome or fatiguing, often creating Pains and ſometimes proving *fatal* [17]? though in the mean time it excites or increaſes the Motion of the Brain, Spirits, and all the Humours? Why Sneezing frequently happens in a Morning after Sleep? And to what People it is of *ſervice* [18]?

[1] There is a wonderful Analogy betwixt theſe Senſes, nor are there any two more nearly related: namely, the ſame ſpirituous Rector is the Object both of the Smell and Taſte; only there is this Difference, that that which is the proper Object of Smell naturally exhales in a volatile State, but that which produces Taſte is leſs volatile. Thus roaſted Meat fills the Noſe of a hungry Perſon, not

not only with its Smell, but alſo impreſſes the Taſte upon the Tongue ſo long as it fumes; but when it is once cold, it only affects the Taſte. For the Organs of theſe two Senſes are very near to each other, ſince the olfactory Membrane of *Schneiderus* is continued from the Noſe to the Tongue, notwithſtanding the Nerves, ſome of which are for the Senſe of Smelling, and others for the Organ of Taſte, ſeem to be at a conſiderable Diſtance. But there are other Inſtances, where the Taſte of a Body being removed, carries off likewiſe the Smell. Thus it is in Cinnamon after its Oil has been extracted; for it then remains incapable of exciting either Smell or Taſte, like a dry Coal; and in the ſame manner the Oil of Cinnamon, which has exhaled its moſt ſubtle Part or ſpirituous Rector, loſes both its Smell and Taſte.

[2] The Nerves here are exceeding tender, very near unto the Brain, and admit only of the moſt ſubtle Parts of Bodies. Even the Medulla of the Brain itſelf ſeems to be expanded in the Noſe; ſince the mammillary Proceſſes are not truly like other Nerves.- The Perſon who has fainted away, is not affected by the moſt high-flavour'd Subſtances applied to the Tongue, nor does he regard the moſt vivid Rays of Light, nor yet the ſtrongeſt Noiſes thunder'd into his Ears. But if to the Noſe of the ſame Perſon is applied Vinegar, or Spirit of Sal Armoniac prepared with Quick-lime, he will be rouſed up with a Convulſion of the whole Body.

[3] *Pechlin* in his Treatiſe *De purgantibus* has demonſtrated by accurate Experiments, that all the Force of purging Medicines does not reſide in their Bulk or Maſs, but in their ſpirituous Rector. Hellebore when it is juſt dug out of the Ground

ſmells

ſmells dangerouſly, and the attracted Vapours affect the whole Body by purging, as I have experienced; but by keeping only, it becomes milder by exhaling that nauſeous Vapour, ſo that at length it becomes an uſeful Medicine. The ſtrong purging Faculty of Coloquintida conſiſts in its odorous Particles, which are very ſmall in Quantity; for when that Drug has loſt its Smell, it becomes quite inactive. The Root of Jalap lately pulverized has a nauſeous Smell, and either vomits or purges. Even in the Glaſs of Antimony, the Matter which excites vomiting is an inconceivable ſmall Part, which being expelled or exhauſted, leaves an inactive Maſs. In the making of the *Emplaſtrum de Hioſcyamo Michaeli*, the exhaling Vapours while it is boiling being drawn into the Lungs, cauſe Faintings. The poiſonous Force therefore of Medicines ſeems alſo to reſide in their ſpirituous Rector.

[4] Some Women continually faint away with barely the Smell of Muſk or Ambergreaſe; and are revived again by Fœtids, which is an Obſervation of *Aretæus* of old. The ſame fragrant ſmelling Perfumes increaſe epileptic Fits, which the moſt fœtid Bodies mitigate; putrefied Bodies create Sickneſs and Vomiting only by their continual Smell. The Fumes of burning Sulphur breathed in large Quantities, either kills the Patient, or greatly endangers his Life. Even the adjacent Brain itſelf ſeems to be affected by Smells, upon the State of which Viſcus the Welfare and Strength of the whole Body entirely depends.

[5] We frequently read in Hiſtory of Perſons killed by Smells in the Courts of Princes. The Fumes of fermenting Wine, however innocent they may be imagined, are a moſt ſpeedy and dreadful Poiſon, from whence Madneſs or a fatal Apoplexy follows.

follows. If a Perſon ſmells to Wine, he will be intoxicated from thence as if he had drank a much larger Quantity; and the like Effect follows from the Fumes of Spirit of Wine. They who handle Saffron in their Hands for a conſiderable time, become ſleepy and often apoplectic. From the Smell of Opium long continued, ariſes Sleep in the ſame manner as if its Juice had been drank. I lately read a wonderful Hiſtory relating to the Efficacy of Odours. Two Mountebanks contending for the Preference of their Orvietan, had a Promiſe from the Magiſtrate of a Licenſe or Privilege to him, whoſe Antidote appeared by Experiment to perform the moſt. The Trial was therefore begun by taking Poiſons themſelves. The firſt Day each took the Poiſon from his Adverſary, and each uſed his particular Orvietan or Antidote; nor did the one or the other ſuffer any Injury. On the next Day when they returned to their former Calling, without any manifeſt Hurt, the one told his Adverſary that he could not any longer contend with him, for he had ſome Kinds of Poiſon which reſiſted the Efficacy of any Antidote; but the other intrepidly denied the Fact. A Drum was therefore brought which was continually beat with Sticks, and his Adverſary ordered to draw Air from thence through his Noſe, to which he raſhly conſented, and immediately periſhed: for his more crafty Enemy had included Toads and Vipers in the Drum, which being put into a Rage by the beating and trembling of the Drum, breathed out a poiſonous Vapour, which immediately exerted its Virulence upon the Seat of Life itſelf; namely, the Brain. For the Heart itſelf, however neceſſary to Life, is yet rather a miniſterial or a ſubſervient Viſcus to the Encephalon.

[6] In ſome People there ſeems to be a particular Diſpoſition of the common Senſory and nervous Syſtem, by which they are violently affected by ſome things which are eaſily tolerable to others. *Sydenham* in his excellent Epiſtle *de morbo hypochondriaco* well obſerves, that there is internally concealed a mere ſpirituous or nervous Man which governs the whole Machine; ſo that we need not wonder that a Motion in one Nerve ſhould excite a Motion in the reſt. Some People have been killed by being ſhut up with Apples, others by ſmelling at Roſes; an Inſtance of which I read in a certain Cardinal, and in a celebrated Phyſician at *Paris*, who fainted away by the grateful Odor of a white Roſe. Others have had the Head-ach from ſmelling at Tuberoſes or Jonquils, whereas the Generality of People are not at all injured by theſe Smells.

[7] There is here nothing ſtrange, or to be wondred at: for the Surface of the Membranes is thus increaſed, upon which the olfactory Nerves are diſperſed; and therefore the Power of ſmelling is thus likewiſe increaſed. If there is but one odorous Particle of Cinnamon in the Compaſs of one ſquare Inch of Air, only that Perſon will ſmell the Cinnamon, whoſe Noſe happens to catch that one Particle: but ſuch a Particle muſt be more eaſily catched by an Organ of Smelling which has a large Surface; whereas it will be more liable to eſcape, and more difficultly perceived if the Organ was ſmall. But the larger the Organ of Smelling in the Animal, ſo much the more eaſily do they perceive Smells; and the longer the Noſe or the more complicated or numerous the Lamellæ of the Oſſa Turbinata, the more exquiſite is the Smelling. All that Part which is above the Noſe in the Horſe or Ox, is filled with the Organ of Smelling. Thoſe quick-ſcented Dogs are the beſt which have

the longeſt Noſes; for the whole Snout is filled according to the Obſervation of *Du Verney* with the Oſſa Spongioſa. But in this reſpect the Elephant is more ſagacious than the quick-ſcented Dog. For to this vaſt Quadruped, Nature has given Joints that are not eaſily flexible, and has connected the Head by a ſhort Neck to the Body; but that the Elephant might be capable of taking its Food from the Earth, Nature has provided the ſame Animal with a long Arm or Snout extended from the Head pendulous, without which this vaſt Animal would have been ſtarved. Thus the *Romans* deſtroyed the Elephants (which they called *Lucæ Boves)* in their Battle with *Pyrrhus*, by cutting off their Snouts; and the ſame Method is uſed at this Day in the *Indies*. But the Eyes of an Elephant are ſo diſpoſed on the Sides of the Head, that they cannot be eaſily directed towards the Earth, ſo as to look conveniently round for Food; and therefore this Snout is filled with olfactory Nerves, inſomuch that the whole Proboſcis, according to the Obſervation of *Du Verney*, is a ſort of Production of the olfactory Nerves. By this means the crafty Animal is enabled to pick out a ſingle Piece of Money mixed among a thouſand others, only by the Effluvia left upon it by the Hand of its Maſter, as I have ſeen myſelf. Even in the Fiſh-kind of Animals, *Steno* has demonſtrated large olfactory Nerves, like two Hands, extended to the Noſe like the optic Nerves, that they might be able to diſcover their Prey at a great Diſtance.

[g] Theſe Birds excel other Animals both in their Sight and Smell. The Falcon, Eagle, and Vulture aſcend and fly through the higher Regions of the Air, that they may the better collect the Scent of the Birds, or other Animals, which lie at a conſiderable Diſtance below.

The

9 The Particles which excite Smelling are incredibly minute: A ſingle Drop of the true Oil of Damaſk Roſes will render a whole Pound of common Oil extremely fragrant; and yet that Pound of Oil, whoſe odorous Part was but a ſingle Grain, will continue to exhale its fragrant Smell to a large Diſtance for many Years. Mr. *Boyle* had a Pair of Gloves in which the Smell of the Ambergreaſe continued for above twenty Years, and yet ſmelt very ſtrong whenever he opened them. I formed a Paſtil of Muſk, Ambergreaſe and Civet mixed in a certain Proportion, and placing it in a wooden Cheſt not accurately cloſed, it has continued there for above thirty Years, ſtill retaining its Fragrancy in a great meaſure: yet it does not ſmell at all times equally ſtrong; for when the Air is moiſt or ſuddenly changed, it ſmells more intenſely, whereas at other times it is very weak. The whole Affair ſeems to follow from the Minuteneſs of the odoriferous Particles, which no one could ever diſcover even by the Microſcope, either in the Flower itſelf, or flying off from it in the Air; no one could ever perceive them either by the Taſte or Touch: but at the ſame time in theſe wonderful minute Particles, there is Force enough to briſkly affect the Noſe. Thus we may account for the perpetual Exhalation of Effluvia from odorous Bodies without loſing any of their Weight, or at leaſt without their ſuffering any ſenſible Diminution. But it may be aſked, Whether or no the Air does not communicate ſomething to the fragrant Bodies, which repairs the Weight which they loſe? Thus it ſeems to be.

10 The fœtid Smell which is ſometimes imprudently drawn in from a putrefying Carcaſs, oftentimes leaves a troubleſome Impreſſion for a whole Day together, the Particles being confined as it

were in the viſcid Mucus of the Noſe. The Truth of this may be eaſily proved by any one who ſmells at the Vapours of a rotten Egg in the Morning.

[11] In ſneezing there is firſt perceived a kind of Titillation under the Os Ethmoides, and then the Perſon waits attentively for the Effort which is to follow, which begins firſt with a kind of Titillation about the Diaphragm and Scrobiculum Cordis, which is always followed with a convulſive Motion or Contraction of the Muſcles belonging to the Thorax and Abdomen. Medicines ſeem to excite ſneezing, when they are ſtrong enough to velicate not only the olfactory or firſt Pair of Nerves, but alſo the fifth Pair; which laſt being very irritable, a convulſive Motion eaſily follows. The Noſe therefore and common Senſory of the Nerves ſeem to be very irritable, and the moſt eaſily moved of any of the moving Nerves, namely, thoſe Nerves are here intended which we call the firſt and the fifth Pair. For a Nerve laid naked in any other Part of the Body by a Wound, does not excite Pain when touched with a Feather; whereas if the ſame Feather irritates the Noſe, it produces convulſive Motions and wonderful Geſtures of Body. But though the ſtrongeſt ſcented Bodies excite ſneezing, yet the reverſe of that Axiom does not follow, namely, Sternutatories do not excite Smells; for Hellebore and Antimony excite violent ſneezing, and yet they do not afford any Smell.

[12] Namely, it ſerves to defend the Nerves and Membranes from being dried up by the Air, preſerving them at the ſame time in a proper Condition for ſmelling.

[13] The Smelling is dull of a Morning, becauſe the Mucus which has been collected and inſpiſſated during

during the Night-time covers over the olfactory Nerves, ſo that they cannot be affected by the odorous Body.

[14] But the Senſe of Smelling is ſharper after Sneezing, becauſe the Air expelled from the Lungs with a conſiderable Force, abrades and carries off a great Part of the Mucus which covered the olfactory Nerves, and render'd them leſs ſenſible. But by the ſame ſneezing alſo the Brain itſelf is ſhook, and the quieſcent Spirits are excited into Motion. We read of a certain Philoſopher, who when he was about to write any thing upon a difficult Subject, purged his Body firſt with a Sternutatory, or with white Hellebore.

[15] The Ancients were of this Opinion. *Galen* and his Followers teach, that the Brain depoſits its Mucus through the Os Cribriforme into the Noſe: and from hence aroſe a Phraſe of the Poets concerning ſtupid Men having Mucus within their Skull inſtead of Brains; but cautious and cunning Men were ſaid by them to be of a quick-ſcented or clean Noſe *(emunctæ naris.)* But the Falſity of this has been proved by *Schneiderus* in his voluminous and extenſive Work *De Catarrhis*; which Book would be certainly for ever in uſe, if the true and ſerviceable Obſervations were collected and contracted into one Volume apart from the uſeleſs Quotations of Authors, and empty Appearances of Learning. But the Opinion of the Ancients may however be excuſed, inaſmuch as the Mucus of the Noſe is ſeparated from the Blood of the external carotid Artery, which may poſſibly, by the Laws of Hydraulics, free the Blood of the internal Carotid ſent to the Brain from its more viſcid Parts, as we obſerved before at §. 231.

[16] This Communication may be explained by the Tables of *Lower* and *Willis*: for it there ap-

pears that the Branches of the fifth Pair of Nerves are diſtributed to the four Muſcles of the Eye, to the Organs of Hearing, and to the Noſe, and that they communicate by a Ganglion with the eighth Pair; but the eighth Pair communicates with the intercoſtal and abdominal Nerves: and therefore all thoſe Parts will be affected at the ſame time in ſneezing; for among the other Nerves, when one is put in motion, all the reſt are agitated; as if, for Inſtance, you ſhould ſuddenly touch the Hand of a Man full of Thought with a cold leaden Bullet, his whole Body will be ſuddenly ſhook or agitated.

[17] Sneezing repeated two or three times after Sleep, renders a Perſon briſk, and clears the Organs of Smelling from their redundant Mucus; but if the ſame Action be repeated twenty times, it greatly weakens by reaſon of the Convulſion of the Nerves, and excites a Pain in the tendinous Circle of the Diaphragm. I ſaw a certain Schoolmaſter, who being very fond of Roſes, had one given him by a miſchievous Boy, which had been ſprinkled over with the Powder of white Hellebore; the Maſter eagerly ſnuffed up the poiſonous Duſt from the Roſe, but was by that means flung into ſuch violent Sneezings, that he would have perhaps expired convulſed in a Tetanos, if the ſneezing had not been ſuppreſſed by ſnuffing up Milk in large Quantities.

[18] It is a common thing for Men, Oxen, Horſes, *&c.* to ſneeze at the firſt Approach of the Light, when they awake in the Morning; for the ſenſible Parts of the Noſe are irritated by the Mucus, which has been accumulated in the Night-time; and this ſneezing removes the Cauſe of itſelf, and at the ſame time reſtores the Organs of Smelling to the diſtinct Perception of Smells.

Of

Of the SIGHT.

§. 508. UPON the moſt prominent or riſing Part of the Os Frontis, is ſeated a thick and arched *Buſh* [1] of Hairs, called the Eye-brow; and in the external Margins of the Eye-lids, called Cilia, are placed a Row of erect, *ſtiff* [2] and crooked Hairs ariſing from their bulbous Roots in the *Cilia* [3]; and both theſe Aſſemblages of Hairs *defend* [4] the Eye, as well below and on each ſide, as above, ſerving to keep Duſt or flying Inſects from falling eaſily in to injure the Cornea.

[1] This moſt exquiſite Organ of Senſe is ſeated in the higheſt Part of the Body, namely, in the Head, which ſtands upon the moveable Neck, as upon an Obſervatory or Turret; from whence every thing may be ſeen both before, behind, above, below, and on all Sides. The Eye-brows ſtand out in ſuch a manner, that they cover and conceal the whole Body of the Eye from every thing that might fall upon it from above: and that they might project farther, the Os Frontis in that Part ſeparates into two Tables, the outermoſt of which being removed forward to form Part of the frontal Sinus's, is the Seat of the Eye-brow.

[2] Theſe Hairs differ conſiderably from all others in the Body, both in their Rigidity and particular Incurvation; for they are inclined parallel to the Horizon, and lie ranged over each other in ſeveral Rows.

[3] The Cilia are ſtill more wonderful, being ſeated in an horizontal Poſture in the Margin of the Eye-lids, ſo as to reſemble very much the Bars or Palliſadoes which are placed round a City for its Defence, which they are very much like when viewed on one ſide. In the lower Eye-lid there are very few Hairs, becauſe that way the Weight of ſmall Bodies hinder their entring into the Eye. But when theſe Hairs are pulled up by the Roots for the Cure of a Trichiaſis, the Perſon is continually obliged to wink and ſhut his Eye-lids, leſt the Eyes themſelves ſhould be injured; and there is an incredible Uneaſineſs ariſing from the ſmall Particles which continually irritate the Globe of the Eye. Theſe, together with the Eye-brows, defend the Eyes from too ſtrong a Light; and therefore old Men who have loſt theſe Hairs, are obliged to defend their Eyes with their Hand in all ſtrong Lights.

[4] Leſt any Sweat or Humour ſhould diſtil from the ſmooth Forehead into the Eye, or leſt any Duſt or ſmall Inſects with which the Air is filled, ſhould fall into the Eye.

§. 509. The Depreſſor *Muſcle* [1] of the Eye-brows ariſing from the Os Frontis on each Side the Noſe, where it joins the anterior Proceſs of the Os Frontis, is inſerted by ſmall Tendons under the elevated Part of the Eye-brows; and by the Action of this Muſcle, the Eyes are ſtill more defended from Dirt (§. 508.), and are alſo ſhaded when placed in too ſtrong a Light; when this Muſcle is contracted, the Eye-brow is drawn towards the upper Eye-lid, and the two Eye-lids are brought

brought nearer together by it at the ſame time; but the Muſculus frontalis *raiſes* [2] the Eye-brow again to its former Situation when that is neceſſary.

[1] That the Eyes might be the better defended, it was neceſſary for the Brows to be moveable. To this Office therefore ſerves the Muſculus frontalis, a cutaneous thin Muſcle called Panniculus carnoſus by the Ancients, who deſcribed the ſame as if it was ſeated throughout the whole Body, being led into that Miſtake from their Diſſections of brute Animals. This thin Muſcle is eaſy to be diſcovered in the Horſe, Dog, and moſt other Animals, in which it ſerves for them to ſhake the Skin of the whole Body, ſo as to throw off Inſects, Flies, and other Nuſances, which they cannot remove by Hands, of which they are deſtitute. But this cutaneous Muſcle is by the Moderns no where found but in the Forehead, Face, Neck, Hands and Scrotum, which Parts of the human Body are moſt expoſed to external Injuries. The Fibres of this Muſcle in the Forehead are ſpread under the cellular Membrane, where they are by *Du Verney* juſtly divided into the Depreſſor Superciliorum and Corrugator Frontis; and before him, *Euſtachius* had depictured the ſame as a threefold Muſcle. The latter draws the Eye-brows nearer together; and at the ſame time depreſſes them towards the Noſe. The Uſe of this Muſcle is therefore threefold: 1. To draw the Eye-brows together, and depreſs them; by which means the Hairs of the Eye-brows are brought nearer to the Eye-lids, to defend the Eye from Duſt, or other Particles which might ſlip into it; and therefore we draw down our Eye-brows when we walk through a duſty Place. 2. They ſerve as a Shade

to

to moderate the too ſtrong Rays of the Sun when we walk in the Day-time; as we ſee naturally follow, when we front the Noon-ſun, or any other ſtrong Light. 3. When we endeavour to diſcern very diſtinct Objects, we draw the Eye-lids cloſer together and form a Shadow, under which the Pupil dilates itſelf, ſo as to receive a greater Number of the diverging Rays coming from the diſtant Object. And this is the Reaſon why old People ſee more diſtinctly through a Tube which is black on the Inſide.

[2] It elevates the Eye-brow whenever the ſquare Muſcle of the Occiput retains the frontal Muſcle to which it is continued; for then the Direction is changed, and the Eye-brows are drawn backward and upward over the Forehead. And this happens whenever we ſuddenly look upward and rejoice. Hence a ſmooth Forehead ſignifies a quiet Mind. But the Fibres of this Muſcle do not run directly upward, but obliquely, as *Euſtachius* has juſtly exhibited in his Tables.

§. 510. The two *Eye-lids* [1] are *membranous* [2], thin, folding together, repleniſhed with *Veſſels* [3], and furniſhed with nervous *Papillæ* [4] on their Inſide which is continually *moiſtened* [5]; being defended with a broad *arched* [6] Cartilage in their Margins where they meet together; and theſe by their opening, ſhutting or winking by an alternate Motion, do likewiſe *defend* [7] and cleanſe the Eyes. For the *elevator* [8] Muſcle of the upper Eye-lid, ariſing narrow and fleſhy from the Bottom of the Edge of the bony Orbit, paſſes over the elevator Muſcle of the Eye, and expanding itſelf into thin tendi-

nous

nous Fibres, is wholly inſerted into the upper Part of the Tarſus, or cartilaginous Edge of the Eye-lid; and it ſerves by its Motion to raiſe or draw up the ſuperior Eye-lid without Wrinkles. But the Sphincter or *round Muſcle* 9 of the Eye-lids ariſing from the larger Bone of the Noſe, and ſpreading its orbicular Fibres over each Eye-lid, it ſerves by contracting itſelf like a Sphincter to apply them by a moderate Motion towards each other, and by a ſtronger Contraction to preſs them againſt the Globe of the Eye, as well as to expreſs the Tears, and apply them to the external Surface of the Eye, ſo as to waſh away the Sordes. But the lower Eye-lid is opened by a ſpontaneous Contraction of *muſcular Fibres* 10 diſtributed into the Cheek.

[1] They are a Sort of Curtains, freely moveable over the Eyes, which they cover in Sleep, and which ſerve to cleanſe the Eyes and keep them moveable. For there are two Lids belonging to each Eye, divided from each other by an horizontal Slit.

[8] The Eye-lids are compoſed of the following Membranes. 1. The Cuticle which is extremely thin, as evidently appears when it ſcales off towards the Declination or End of an Eryſipelas. 2. The true Skin itſelf, which is very thin. 3. The cellular Membrane as thin as the Web of a Silk-worm, though it wonderfully ſwells in Diſeaſes, even from a ſlight Cauſe, as in the Small-Pox, or an oedematous Eryſipelas, where it is ſometimes an Inch thick. Alſo in the Beginning of a Dropſy there appears a diſtended Tumor round

round the Eye, which is commonly, with good Reaſon reckoned among the Signs of a Deficiency in the vital Powers. But this Part of the cellular Membrane is never diſtended with Fat, even in the moſt corpulent Perſon. 4. The muſcular Expanſion of the elevator Muſcle, which is lined with a vaſcular Stratum. 5. The Stratum of Papillæ. 6. An exceeding thin Membrane like a Spider's Web, deſtitute of any Skin, Cuticle or Glands, and lying next to the Eye itſelf, being ſo ſubtle and pellucid that upon turning back the Eye-lid, one would imagine that they ſaw the naked Veſſels without any Covering; when at the ſame time they are inveſted with this fine Membrane. Thus are the Eye-lids compoſed of ſo many thin Membranes, ſo as to be elevated and depreſſed without any apparent Wrinkles.

[3] The numerous Veſſels of the Eye-lids are demonſtrated by filling them with ceraceous Injection. And even upon turning back the Eye-lid in a living Perſon, the whole appears a dreadful Spectacle diſtended with red Blood, ſuch as we never obſerve in the Skin of the Face; nor are the Arteries in any Part of the Body expoſed ſo naked as in this. By theſe numerous ſmall Arteries therefore, the Eyes are maintained warm, while the other Parts of the Face are cold: for theſe numerous ſmall Veſſels of the Eye-lids continually adminiſter Warmth to the Eye and its Humours. Theſe ſame Veſſels alſo diſcharge a thin inſipid Water, with which the Eye is moiſtened.

[4] The convex Surface of the Eye lies under the concave Part of the Eye-lids, which being deſtitute of the Skin and Cuticle, are only covered with ſo thin a Membrane, that the leaſt Violence deſtroys it. But to prevent a Deſtruction of this Membrane, Nature has placed a faithful Guard to

give

give Notice; namely, Pain, which is ſeated in the numerous and naked Papillæ. Theſe Papillæ are demonſtrable by cutting off a Part of the Eye-lid and macerating in Water; by which means the whole internal Surface appears unequal or villous, like fine Velvet: but ſo ſenſible are theſe Papillæ, that the ſmalleſt Particle of Sand ſlipping betwixt them and the Eye, excites a moſt intenſe Pain, which never ceaſes till there is a Quantity of Tears ſent to the Eye, ſufficient to waſh out the offending Matter; but if the offending Body is not thus naturally waſhed out, warm Water is to be injected by a fine Syringe betwixt the Eye and its Lids; by which the offending Matter may be diſcharged, and the injured Eye-lids relieved. If quick Lime falls into the Eye it produces the moſt extreme Torture, and ſometimes even Blindneſs itſelf; and in this Caſe there is no other Remedy than to take a Mouthful of Water made warm, and blow it betwixt the Eye-lids turned back. But when an Opthalmia or other external Diſorder has deſtroyed the thin Skin of the Eye-lid, an intenſe Pain continues Day and Night, which cannot be removed but by injecting Milk or the Blood of young Pigeons.

[5] This moiſtening Liquor ariſes from the hygropthalmic Ducts of *Meibomius*, and from the Vapour of the exhaling Arteries conjoined together; the former is properly the Tears, but the latter exhales in the Form of a Vapour, betwixt the Convexity of the Eye and the Concavity of its Lids, that the Membranes touching each other might not be very dry, which would certainly cauſe them to grow together, ſo as to produce a Symblepharoſis, but which is called by *Celſus* and the Ancients Ancyloblepharon. This is a lamentable Diſorder, but curable by continually injecting ſome emollient

emollient and diluting Liquor Day and Night. Hence it frequently happens that the Eye and its Lids grow together in the Small-Pox and Meaſles; and in this Caſe neither the Eye-lid alone, nor the Eye itſelf can be elevated. Thoſe who are afflicted with this Diſorder cannot turn their Eyes upward, unleſs aſſiſted by the Hand of the Surgeon; but the leſs knowing Phyſicians often falſely aſcribe this Diſorder to a Palſy.

[6] A very exact Segment of a Circle, whoſe Circumference includes the Edge of the Eye-lids. Theſe Tarſi being cartilaginous, do by their Firmneſs keep the Eyes parallel and free from Wrinkles in all Poſitions, ſo that they never collapſe either when they are elevated or depreſſed. For unleſs the whole Eye-lid was kept equally ſtretched, it would be continually wrinkled at the time of its Elevation, and the Wrinkles would riſe up towards the larger Angle of the Eye, not without ſome Uneaſineſs to the adjacent Parts.

[7] The Eye-lids ſerve, 1. To keep the Eyes moiſt externally, that they may never become dry, wrinkled, or opake. 2. To cover the Eyes in the Night-time, which would otherwiſe be ſoon ſpread over with a Cruſt, ſo as to be ſtopped up by the Duſt which continually floats in the Air. 3. To cleanſe the Eye every Moment, almoſt in the ſame manner as Flies, who that they may aſcend a very ſmooth perpendicular Plane, as Glaſs, are furniſhed with little Hooks in their Feet, which they continually rub and cleanſe with their Forefeet, leſt they ſhould become uſeleſs by their being covered over with any viſcid Matter. Thus our Eye-lids are continually moving Day and Night, to wipe off and remove the Duſt, which flying in the Air might concrete with the Humours of the Eye, and incruſt it over.

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[8] This was firſt depicted by *Euſtachius*, and afterwards deſcribed by *Fallopius*, though the Uſe of it was not well underſtood by *Lanciſi*. It ariſes tendinous from the bony Arch of the Orbit, and aſcends over the Rectus Attolens Muſcle of the Eye, and betwixt the cellular and papillary Membranes of the Eye-lid; its fleſhy Fibres are ſpread like rays, and continued even to the cartilaginous Edge or Tarſus, into which they are inſerted tendinous. When theſe muſcular Fibres are contracted, they raiſe or elevate the Eye-lid equally on all Sides; but the Action of this Muſcle is aſſiſted by the adjacent Fat lodged in the cellular Membrane. This Muſcle is very diſtinct from the right elevating Muſcle of the Eye; and from hence Anatomiſts have taken occaſion to reckon ſeven Muſcles for the Motion of the Eye. When this Muſcle is convulſed, as it ſometimes happens in Epilepſies, the Eye ſtares and remains continually open. Surgeons ought to be careful that they do not cut this Muſcle in the middle; for it would be followed with an incurable Palſy of the Eye-lid, which falling down would in a manner bury the Eye itſelf. To cure this Diſorder, *Bartiſchius*, a *German*, in his very ſcarce Treatiſe entitled *Ophthalmodulia*, orders the Eye-lid to be intercepted betwixt the two wooden Pliers, cut off, and afterwards conſolidated; thus the Eye-lids are prevented from collapſing or deſcending too low upon the Eye in a diſagreeable Manner. There has been alſo a Controverſy about the ſame Operation, betwixt *Ruyſch* and *Raw*.

[9] This orbicular Muſcle antagonizes the former, being in ſome meaſure aſſiſted in its Action by the Weight of the Eye-lid. It ſtrongly draws the Eye-lids into mutual Contact, depreſſes the upper Eye-lid

Eye-lid and elevates the lower, ſhutting up the Eye or permitting it to ſee only through a ſmall Fiſſure betwixt the Eye-lids, at which time the elevator Muſcle is at reſt. This orbicular Muſcle being much ſtronger than its Antagoniſt, ſhuts the Eye with an almoſt irreſiſtible Force, at the Approach of Sleep, as we ſee in Children, who at an Entertainment are neither willing to leave the Company, nor yet are they able to keep their Eyes open. And even adult Perſons being awaked out of a Doze, are ſcarce able to overcome the Power of the orbicular Muſcle, except by rubbing their Eye-lids. This orbicular Muſcle ſerves alſo to cleanſe the Eye; for by contracting the Eye-lids, it preſſes out the Tears, and moving them over the Surface of the Eye, it at length expreſſes them together with the Sordes diſſolved or mixed with the Tears. But their fixed Point or Origin being towards the Noſe, they make the Globe of the Eye turn that way; and as the ſame Muſcle ariſes and is diſtributed before the Eye, it preſſes the Globe backward into the Orbit. But the Bulb of that Eye being thus repelled compreſſes the lacrymal Gland, ſo as to force out the Tears, which are there ſeparated. Obſtinate Children when they endeavour to move their affectionate Mothers to grant what is denied, ſqueeze the Balls of the Eyes with their Fiſt, and by that means force out the Tears from them. This Muſcle being violently contracted in a ſtrong Light, or in a ſorrowful Diſpoſition of Mind, occaſions the Tears to flow ſo plentifully that they run down the Cheeks. Whores craftily force out Tears by the Action of this Muſcle, to move and reduce the Minds of young Men to a Compliance. Laſtly, this Muſcle is ſeated in the cellular Membrane; and hence it is that it does not corrugate the Eye-lid.

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[10] The lower Eye-lid is depreſſed, 1. By its own Weight. 2. By the Muſcles of the Cheek drawn downwards, and detracting the very moveable Eye-lid at the ſame time. When the Fat of the Cheeks has been conſumed by extreme Leanneſs, and the Muſcles of thoſe Parts are more contracted, theſe Fibres are not raiſed above the lower Eye-lid, nor is the Eye quite ſhut, but ſome Part of its White appears uncovered. Hence *Hippocrates* ranks the Appearance of the White of the Eyes in Sleep, among the Signs of Death; except the Diſorder ſhould ariſe from a mere ſhrinking or Smallneſs of the Eye-lids. *Du Verney* wrote to me formerly, that he had found an orbicular conſtrictor Muſcle ſhutting the Eye-lids, which had two Bellies with an intermediate Tendon. But afterwards in his Letters ſince wrote, he takes no notice of the Diſcovery; whence it would ſeem that he had met with ſomething accidentally, which does not frequently occur.

§. 511. But leſt the Eye-lids ſhould be excoriated by continually ſtriking againſt each other in *winking* [1], therefore there is a Row of ſmall *Glands* [2] like little Grains of Sand, ſeated in the cartilaginous Edge of each Eye-lid, and which ſeparate a yellow Humour, as if it were compounded of Oil and Wax mixed together, diſcharged by open Ducts, perforating the cartilaginous Tarſi of the Eye-lids themſelves: the Mouths of theſe excretory Ducts are the Extremities of ſmall Veſſels, which are here diſpoſed in a ſerpentine Courſe, and ariſe immediately from the ſmall Arteries, which are here diſtributed, without any intermediate glandular Fabric.

[1] The cartilaginous Tarſi continually ſtrike and rub againſt each other in winking with the Eyelids; inſomuch that we ourſelves, or our Friends ſtanding by, may hear a Sound as if it proceeded from the Colliſion of elaſtic Bodies, provided there is a profound Silence. But ſuch frequent Percuſſions repeated perhaps more than a thouſand times in a Day, and that with ſome Violence, muſt neceſſarily by the Attrition wear away the Parts in contact, inſomuch that ſometimes we have ſeen little bleeding Fringes from the Attrition of the Perichondrium or thin Membrane which inveſt the Cartilages of the Tarſi; but to prevent this Accident they are furniſh'd with theſe Glands ſeparating this unctuous Humour.

[2] Theſe ſmall Glands are conſpicuous enough upon turning out the Eyelid, appearing like ſmall Grains, by preſſing which a ſort of Liniment is diſcharg'd, which mixing with the glandular and arterial Humour, forms part of the Tears. Theſe ſerpentine Inflexions of the Ducts have been demonſtrated by *Ruyſch*, and his red Wax being happily injected, has return'd white thro' theſe Ducts, whence he rather eſteems them Continuations of the Arteries than real Glands; they ſeem in ſhort to be no more than Cryptæ, into each of which many ſmall Arteries meet together, and diſcharge an aqueous Humour, which by ſtanding grows viſcid and thick, and is expreſſed at the time of winking, ſpreading itſelf over the cartilaginous Margins of the Eyelids, which it lubricates, and being dry'd up appears like a white inſipid ſcaly Matter. When this Liniment is abſent, the cartilaginous Margins of the Eyelids rubbing together are inflam'd, and glue together in the Night-time, inſomuch that they can be ſcarce open'd in the Morning without the Aſſiſtance of warm Water.

ter. In theſe glandular Cryptæ, like ſmall Grains, are formed thoſe ſmall Tumors which are called by the Name of *Chalaza* or *Hordeolum* of the Eyelids, which may at length turn into an *Atheroma*; theſe are found as well in the Margin of the upper as the lower Eyelid.

§. 512. The large conglomerate Gland, termed *Glandula innominata*, being broad, flat, and unequal, is *ſituated* [1] within the Orbit, towards the external Angle of the Eye, near the rough Fiſſure or Chink, being involv'd in Fat, and furniſh'd with Arteries, Veins, Nerves, and lymphatic Veſſels, with hygrophthalmic *Ducts* [2], diſcharging the Moiſture which *waters* [3] the Eye; this Gland ſeparates a brackiſh, watery, pellucid Humour from the arterial Blood, which is mild to the Taſte, and continually diſcharg'd in a ſmall Quantity, but *abounds* [4] more plentifully when the Eye is rubb'd, or when this Gland is compreſſed together with the Eye by the Action of the orbicular Muſcle of the Eyelids; ſo that by the Flux of this Humour from above, betwixt the Globe of the Eye and the internal Surface of the upper Eyelid, the Eye itſelf is continually moiſten'd, lubricated, waſh'd clean, and the Eyelids themſelves prevented from growing together. When this Humour is redundant, or ſeparated in too large a Quantity to be abſorbed by the lachrymal Points, it is call'd Tears. The ſame Humour may perhaps be likewiſe ſeparated for the ſame Uſes by ſmall Glands ſeated in the upper Eyelid.

[1] This Gland is ſecurely ſituated in a ſort of Excavation within the Orbit, which ſeems as if it was impreſſed by the Thumb, the Length of it being nearly equal to one third Part of the Orbit. This Gland is the Seat of great Diſorders, for it ſometimes degenerates into a Scirrhus and a Cancer, thruſting the Eye itſelf out upon the Cheek; nor is a Tumor of this Gland to be remov'd without the greateſt Difficulty, if at all; if therefore an Inflammation is perceiv'd in this Part, all proper Aſſiſtances are to be timely uſed, that the Patient may not for ever after be troubled with an *Oculus Elephantinus*, or protuberant Eye.

[2] Which Ducts always run in great Numbers thro' the internal Membrane of the concave Surface of the Eyelid, opening here and there obliquely, and watering the external Convexity of the Eye.

[3] That the external convex Surface of the Globe of the Eye may continue ſmooth, and waſh'd clean from all the ſmall Particles which may fall into it from the Air, which abounds with Duſt, Inſects, and other Nuſances. There was the greateſt Neceſſity for the Eye to be continually moiſten'd with this Humour; for the Laws of Dioptrics require the Eye to be always of the ſame Figure, for which reaſon it is continually diſtended with extravaſated Humours internally. But together with this Conſtancy of Figure, the Eye was required to be flexible (*per* §. 530.) and therefore that Flexibility made it neceſſary for the Eye to be continually moiſtened.

[4] In ſorrowful Affections of the Mind the orbicular Muſcle of the Eyelids ſtrongly compreſſes the lachrymal Glands, as alſo it does in various Pains and Inflammations of the Eye. When a little Particle of Sand, or a ſingle Drop of Vinegar has

has fallen into the Eye, the orbicular Muſcle contracts and preſſes the lachrymal Gland, and continues waſhing the Eye until the offending Body is diſcharged. Nor can the Influence of the Will ſuppreſs this Flux of Tears. Laſtly, this lachrymal Humour runs down over the Cheeks, whenever the pituitary Membrane is tumefied, ſo as to compreſs the naſal Canal, that its Capacity is not ſufficient to receive or tranſmit all the Humour, which when redundant from any Cauſe, ſo as to run down the Cheeks, is called Tears.

§. 513. But both theſe Humours (512) together with the abſterged Sordes, are directed by the determinate *Figure* 1 and Concourſe of the cartilaginous Margins of the Eyelids towards that *Space* 2, which is left free in the larger Angle of the Eye for the Reception of them, and for the ſpongy Caruncle which is there ſeated; and here the *groſſer* 3 Parts being ſtopped, and gather'd together upon the rough Surface of the fore-mention'd Caruncle, are at length dry'd into gummy Scales; but the more fluid Parts are wonderfully preſſed by a determinate Motion into the dilated Points or lachrymal *Foramina* 4, ſeated in the extreme Angle of each Eyelid, and uſually denominated the *Puncta lachrymalia*; from whence the lachrymal Ducts ariſing, meet together behind the Caruncle into the lachrymal *Sack* 5 ſeated in the naſal Canal, which is formed by the Concourſe or Meeting of the *Os unguis* with the anterior Part of the upper Jaw-bone; from which Sack the Humour is

continually diſcharged by an open Duct into the Cavity of the Noſe, immediately under the lower *Os ſpongioſum*; hence appears the reaſon why thoſe that cry have a Running at the Noſe, and why there is not the Appearance of any lachrymal Humour in People who are under no Uneaſineſs.

1 The orbicular Muſcle firſt compreſſes the Part where there is the leaſt Reſiſtance, namely, the external Angle of the Eye, and from thence it gradually proceeds, contracting towards the larger Angle; and thus by a mechanical Neceſſity the Humours of the Eye are determined from the external towards the internal Angle.

2 The cartilaginous Margin of the Eyelids is broke off towards the internal Angle in ſuch a manner, that in that Part the Eyelids do not touch each other, but leave a ſmall intermediate Space; in that Space is ſeated the *Caruncula lachrymalis*, as it is commonly, but improperly, call'd; namely, a particular kind of fleſhy Subſtance, much reſembling a Strawberry, and on all Sides beſet with moſt minute Hairs, as they are call'd by *Morgagni*, from whence the Ancients falſely imagin'd the Tears to ariſe; this Subſtance is therefore formed by Nature to fill up the Space left betwixt the Eyelids, and to ſerve as a Strainer, to ſtop the Sordes from entering and obſtructing the lachrymal Points.

3 The Fæculencies being excluded from the Orifices of the lachrymal Ducts, are ſtopt and retain'd by the moſt minute Hairs of the Caruncles; where being collected, they are at length condenſed into rough Scales, which ſeldom appear in the Day-time, becauſe we then frequently clear the

Eyes

Eyes by rubbing them; but in the Night-time they are often found, even in the moſt healthy People, being the white Subſtance ſo frequently mention'd by *Hippocrates*. When we walk thro' the Duſt there is by this means form'd ſuch a viſcid and opake Cruſt, that it obſtructs the Eye, and renders it neceſſary to waſh it off. Theſe Sordes are compoſed, 1. Of the unctuous Liniment from the ſebaceous Glands *(511.)* 2. Of the Duſt and other Particles catch'd and receiv'd from the Air. 3. From the groſſer Parts of the lachrymal Humour itſelf. Theſe Fæculencies are collected in greater Quantities in the Eyes of Brutes, more eſpecially in thoſe which live in duſty or ſandy Places, as in the Elephant and Stag, in which they degenerate into Stones, being receiv'd by the *Arabians* among the officinal Simples under the Title of *Lapides de oculis cervi.*

[4] Theſe Points or Foramina are ſo large that they are capable of receiving a Briſtle; thro' theſe all the Humour is abſorb'd, which is preſſed from the lachrymal Glands by the winking of the Eyelids, while groſſer Parts are ſtopt by the lachrymal Caruncle.

[5] This Sack is a Cavity, formed without by Membranes, and within by Bones joined together, namely, the *Os unguis* and upper Jaw; to which Sinus the Tears are conveyed in a direct Courſe thro' the lachrymal Points, or any other Humour that is injected betwixt the Eye and its Lids inſtead of the Tears; and from this Sack the Humour is diſcharged by a continued Canal running under and parallel to the Eye above the Palate, and into the Cavity of the Noſe. From this Fabric of the Parts which we have hitherto explain'd, ariſe four Kinds of lachrymal Fiſtulæ; the firſt of which is when the lachrymal Points being lacera-

ted, inflamed, or excoriated, grow together; whence the Tears are not abſorb'd, but ſtagnate in the internal Angle of the Eye, excoriate the Eyelid, and make themſelves a filthy Drain, thro' which they perpetually diſtil over the Cheek. The ſecond Species is when the lachrymal Canals grow together betwixt the Sack and the Points; and the third Kind is, when the lachrymal Sack itſelf is obſtructed or concreted together after an Inflammation, or ſtopt up by the inſpiſſated Matter of the Tears. The fourth and laſt Species is, when from any Cauſe the Emiſſary within the Noſe itſelf is obſtructed or compreſſed, whether by an Inflammation or Diſtention of its Membrane in a Cold or otherwiſe; which Obſtruction being removed, the Tears again diſcharge themſelves by their uſual Courſe. All theſe Diſorders are commonly treated, without any reaſon, by one and the ſame Method; namely, by actual or potential Cauteries; when the only true and ſucceſsful Method of relieving the Patient, is by removing the Obſtructions of theſe ſeveral Canals.

§. 514. Thus therefore the Eyes, continually expos'd to the Air, are kept *moiſt* [1], *clear* [2], *tranſparent* [3], ſlippery, *flexible*, or *yielding* [4], ſoft, warm, and *moveable* [5]; and are alſo by the ſame Means readily freed from every thing which is rough or acrid that happens to fall into the Eyes, and are continu'd in a fit Condition to be equally expanded by the internal diſtending Cauſes.

[1] When the Force of the Veſſels is ſo much weaken'd as to deny the uſual Supplies of the hygrophthalmic Liquor, the Eye becomes wrinkled, and

and remains in the middle of Death a moving Spectacle; but ſo long as we continue in Health, Nature takes care not to let this Liquor be wanting. If a Child ſhould be expoſed to the dry Air in hot Weather, the Eye will appear to wink continually as long as it is dry'd by the Air; and thoſe Winkings will be repeated whenever the Eye becomes dry again.

[2] The Eyes in a healthy Perſon look agreeably ſplendid; but when their ſhining is removed, the Eye appears frightful and ſtern to thoſe who behold it.

[3] When the Tears are wanting, the Tranſparency of the Eye is continually impair'd, and it becomes opake, in the ſame manner as when it is dry'd by the Air after Death.

[4] There was the greateſt Neceſſity for the Coats of the Eye to be kept flexible, in order to preſerve the Sphericity of its Figure; for unleſs every Fibre of the Eye remains equally lax, it would not be expanded by the vitrious Humour internally into a perfect Sphere, but would reſemble a Body having many Angles, being moſt prominent in thoſe Points of the Circumference where there is the leaſt Reſiſtance; for *Bernoulli* has demonſtrated, that a Circle will be form'd when the Liquor within preſſes every way with an equal Force upon an equally reſiſting Line. Hence in old People, and in thoſe who are near Death, the Eye becomes ſtiff and flat; and this is the reaſon why thoſe who are long-ſighted are obliged to correct the Flatneſs of their Eyes with a convex Glaſs, which collects the Rays together more than the Eye itſelf. But in dead People the Alteration in the Figure of the Eyes is ſtill greater, and is vulgarly called breaking the Eyeſtrings.

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[5] The Eye is hardly ever at reſt, but is continually moving even under the Eyelids, and when the Eyelids themſelves are at reſt.

§. 515. The *Fabric* [1] of the Eye and the Action of it thence reſulting, will be beſt underſtood if we begin firſt with the optic Nerve, and then proceed to conſider all its other Parts, and their Offices, in that Order in which they depend upon the Nerve.

[1] The Eye may be conſidered as an optical Tube, (as *Perrault* long ago obſerved) whoſe Object-Glaſs is the firſt Membrane termed the Cornea; the Glaſs which brings the Object nearer is the cryſtalline Lens, behind which lies the vitrious Humour; the Partition excluding the refractive Rays is the Eyes with the Pupil and Uvea, and the Choroides performs the ſame Office with the black Tube.

§. 516. The optic *Nerves* [1] proceeding from the upper Part of the medullary Subſtance of the Brain, which lies under the Corpora Striata, deſcend from thence downward, and moſt ſtrictly *unite* [2] together under the Infundibulum; then ſeparating again from each other, they proceed towards each Side from whence they came with their Fibres, and penetrate into the round Foramina in the Bottom of the bony Orbits of the Eyes. Through all this Courſe the optic Nerves continue ſoft and *porous* [3], and are covered only with the thin but tough Pia Mater of the Brain;

Brain; which furniſheth them with a great many Branches of *Arteries* 5, as they paſs along ſecurely under the ſuſpended Brain. But in their Paſſage through thoſe round Foramina of the Orbit, they are alſo covered with the Dura Mater, which like a *Sheath* 5 ſtrongly adheres to the former Membrane; and thus they paſs through the Foramina into the Cavities of the bony Orbits of the Eyes, where the Dura Mater itſelf is alſo found ſpread with many ſmall Arteries.

1 In an Embryo the Eye is much greater in proportion to the other Parts of the Body, than in an Adult; and even as the nervous Syſtem is uſually very large in the incipient Animal, yet the Eyes are in many Kinds of Embryo's almoſt equal to the Brain itſelf. It appears from the Obſervations of *Malpighi*, that the Eyes then bear ſo large a Proportion, as might induce one to believe that the whole animal Machine was only formed for the ſake of the Eyes. The Head is equal to a third Part of the whole Animal, but the Eyes make up half of the Head: and even in Fiſh that are adult, the Brain itſelf is no larger than the Eyes; and in thoſe Fiſh the Eyes are really a Production of the Brain. Thus the Bulk of the optic Nerves is very conſiderable, and paſs through Foramina proper to themſelves, which are not inferior in Size to thoſe of the largeſt Nerves.

2 This Conjunction of the optic Nerves muſt be evidently of the greateſt Uſe, ſince they are conſtantly obſerved in almoſt every kind of Animal. I am almoſt apt to ſuſpect, that half of the Medulla ariſing from the right Corpus Striatum paſſes to the right Eye, and half to the left; and

on

on the other hand, that from the left Corpus Striatum half of the Medulla paſſes to the right Eye, and half to the left: and hence we may poſſibly derive the Reaſon why we ſee but one and the ſame Object when we look with two Eyes. In Fiſh this Conjunction of the optic Nerves is not to be found. In the Chamæleon the Eyes are ſeated laterally in the Oſſa Temporalia, whence this Animal is obliged to turn his Head on one Side to ſee.

[3] The optic Nerves are truly a Production of the Medulla of the Brain, properly ſo called; being quite porous throughout, which we do not obſerve in any other Nerve. In the middle of the Nerve there is alſo a Foramen which was not unknown to *Galen*, and is plainly delineated by *Euſtachius*, who ſeems to be much rejoiced that he had an Opportunity of ſupporting the Opinion of *Galen*, in oppoſition to the other Anatomiſts: and which Foramen though denied by many Writers, is yet conſtantly in the Center of the optic Nerve, and tranſmits an Artery which ought never to be forgot, as it is diſtributed throughout the middle of the Retina. This Artery has been exhibited by *Ruyſch*, and ſeems to have been deſigned by Nature to warm the Medulla of the optic Nerve with the vital Blood. From this Fabric we are capable of accounting for many Appearances and Diſorders of the Eye. An ancient Writer, *Aetius*, obſerves, that in the moſt inflammatory Diſeaſes of the Head, and after a Phrenſy follows an Amauroſis which the *Arabians* call a Gutta Serena, but which is a perfect Blindneſs, in which there is no apparent Change to be ſeen in the Eye. But this Diſorder ſays, *Aetius*, gives way to no Medicine; but when the Diſorder is removed by a ſalutary Criſis, it vaniſhes of its own accord.

accord. For in this Diſorder the ſoft Medulla of the optic Nerve is compreſſed and obſtructed by the Diſtenſion of the circumjacent Arteries.

[4] There are four ſmall Arteries which paſs along to the optic Nerves at its four Sides: but beſides this there are Nerves ſent to the exterior Parts of the Eye, from the third, fifth and ſixth Pair, for Motion and Senſation.

[5] Where the optic Nerves paſs out of the Cranium, they receive a membranous Covering, which does not ſeem to be a Production of either of the Meninges, nor of the Tunica Arachnoides. The Membrane is indeed thick and ſtrong, receiving ſmall Branches of the fifth Pair of Nerves as well as ſmall Arteries, being deſtined for other Uſes different from that of Viſion.

§. 517. Theſe bony *Orbits* [1] of the Eyes are lined internally with the *Perioſteum* [2], which ariſes from the Dura Mater itſelf, reflected back at the ſame Place, where it inveſts the optic Nerve; and being filled with a large Quantity of *Fat* [3], the Globe of the Eye is received and ſecured in the ſame, as upon a Cuſhion: and thus the Eye is defended, lubricated, and rendered eaſily moveable.

[1] Theſe Orbits are formed by Nature of ſeveral Parts of Bones; nor could it otherwiſe be capable of growing or increaſing, ſince a perfect Sphere violently oppoſes Expanſion; nor would the Muſcles of the Eye nor lachrymal Glands permit theſe Cavities to be of a ſpherical Figure. For the Eye continually grows, though it does not increaſe in the ſame Proportion with the other Parts of the Body.

All

[2] All the Perioſtea or Membranes which inveſt the Bones of the Body cohere with the Dura Mater: for this gives a Caſe to the Medulla Spinalis; (§. 304. N°. 4.) and from thence ariſe the external Perioſteum of the Spina Dorſi, together with all the Vaginæ or Caſes of the Nerves.

[3] It is this Fat which in the Eyes of Brutes is ſo reliſhing and agreeable to the Taſte. It ſerves to keep the ſix Muſcles of the Eye perpetually ſoft and moveable. We ſhould not be capable of ſeeing unleſs the Eye was perfectly ſpherical; for if you preſs the Eye with the Finger, ſo as to alter its ſpherical Figure, that Eye will be blind for a little time. This Figure of the Eye ariſes in a great meaſure from the expanding Force of the Humours within; but this would not produce a Sphere unleſs the Membranes gave way equally on all Sides externally, which is moſt happily provided for by encompaſſing them in this Manner with ſoft Fat. When this Fat is conſumed the Eyes appear hollow, ſorrowful, and like thoſe of a dying Perſon. For the Bulb of the Eye is much leſs than the Orbit. In this Fat is the Seat of various Diſeaſes and ſometimes Suppurations, which thruſt out ſometimes the whole Tunica Adnata from the Orbit, without injuring Viſion. In this Caſe, a ſkilful Surgeon perforates the Tunica Adnata by Puncture, with the Scalpell; by which the Matter being diſcharged the Eye recovers its former healthy State.

§. 518. In the next Place the *Vagina* [1] or Covering derived from the Dura Mater to the optic Nerve, enters the Orbit above the forementioned Fat, and ſoon after this external Covering of the optic Nerve expands itſelf

itſelf into a membranous and almoſt perfect Globe, hard and tough, like Leather, wrapp'd round the whole Eye, and growing gradually *thinner* [2], is at laſt more thin, prominent and pellucid in the fore-part, where it is called the *Sclerotica*, ſo far as it is white and opake; but where it is thinner and pellucid it is term'd *Cornea* [3]; it ſerves principally to keep up the Figure of the Eye, ſuſtain its Veſſels, and ſupport its Muſcles with their Tendons; for thro' this Membrane enter the Arteries and *Nerves* [4] of the Eye.

[1] This membranous Vagina or Covering being extended to the Margin of the round Foramen in the bottom of the Orbit, receives the optic Nerve in its middle; and after paſſing a ſmall diſtance together, it is then expanded into the *Sclerotica*, ſo called from its Hardneſs. But I muſt confeſs myſelf to have been formerly of the Opinion of thoſe who ſuppoſe the *Dura Mater* to form the Perioſteum of the Orbit, and make the *Sclerotica* a new and diſtinct Membrane.

[2] It is thickeſt at the bottom of the Orbit or Globe, and is gradually extenuated forwards; thus the Sclerotica of the Eye in a Whale is an Inch thick at the bottom of the Globe, whereas in the fore-part it is hardly four times as thick as Paper; it renders the Figure of the Eye permanent, that it may not be liable to Alteration from the Preſſure of the Muſcles.

[3] In the anterior Part of the Eye we obſerve three diſtinct Colours; the whole Circumference appears white, namely, ſo far as the *Tunica adnata* extends; but in the middle of the *Adnata* appears a grey, light, blue, or Aſh-colour'd Circle, ſometimes

times blueiſh, or inclin'd to red, to which is given the Name of *Iris*; in the Center whereof appears a round black Opening, called the *Pupil.* Before the *Iris*, is expanded the *Cornea*; namely, the Sclerotica itſelf continued, only changing its Name where it changes its Colour and becomes tranſparent. The *Cornea* conſiſts of pellucid Lamellæ, almoſt like thoſe of Horn. When the Eye is thruſt forward ſo as to diſtend the *Cornea*, and you then ſuddenly wound it with a Knife, it diſcharges a great Number of aqueous Drops, which is a Sign that it contains ſmall lymphatic Veſſels. In Inflammations of the Eyes the whole *Cornea* ſometimes looks red, when the red Blood has penetrated into theſe pellucid Veſſels.

[4] The ophthalmic Nerves of *Raw*, ariſing from the third and fifth Pair, which penetrate into the Eye, and perforate the *Sclerotica* in ſixteen different Parts; from theſe Nerves ariſe the external radiated muſcular Fibres of the Pupil, which dilate it, and the internal orbicular Muſcle, which contracts the Pupil, together with the ſmall tranſverſe Muſcles withinſide the Iris, where it lies incumbent upon the cryſtalline Lens; laſtly, thoſe Muſcles which are called the ciliary Proceſſes, which are implanted into the Margin of the cryſtalline Lens above the lateral Ring; all theſe ſmall Muſcles are entirely compoſed of medullary Fibres, into which the ſmall ciliary Nerves are continued and degenerate.

§. 519. But the Membrane which involv'd the optic Nerve being continued from the *Pia mater* [1], and having enter'd the Orbit or Globe of the Eye together with the ſame Nerve, lines the hollow Surface of the Sclerotica,

rotica, and divides itſelf into two Lamellæ or Plates, which are diviſible, and ſpread with an infinite Number of diſtinct Arteries of different Courſes, as appears from the Injections of *Ruyſch*; and thus this Membrane is continued forward to where the Sclerotica forms the Cornea, and there receding *inwards* [2] from the Sclerotica, it firſt gives a very thin Membrane, which is ſpread upon the *vitreous* [3] Humour; and in the ſecond place it forms the *Tunica Uvea* [4], in the middle of which is a Perforation called the *Pupilla* [5]. That Lamella which lies contiguous to and incumbent on the Sclerotica, is term'd the *Choroides*; and the other Lamella which lies within the former, is term'd *Tunica Ruyſchiana* [6].

[1] Which being deriv'd from the *Pia Mater* and *Tunica arachnoides* of the Brain, and changing its Nature, ſo as to become more tough, and being furniſh'd with Arteries, leaves the optic Nerve, and lines or covers the whole Globe of the Eye, except in the round Limb or Circle where the *Sclerotica* terminates and forms the *Cornea*, and where the Eye, which before appear'd white, begins to be painted of a different Colour; for there it deſerts the *Cornea*, recedes inward, and forms a pendulous Membrane under or at ſome diſtance from the *Cornea*, being perforated in the middle by the Pupil; nor could this Membrane poſſibly inveſt the *Cornea* like the reſt of the Sclerotica without obſtructing its Tranſparency, which would have fruſtrated the whole Deſign of the Organ. But the firſt who demonſtrated that the thin Membrane of the Brain is compoſed of two different

Lamellæ, the upper of which is the *Arachnoides*, and the lower the *Pia Mater*, a mere Network of Veſſels, was one *Matthew Slade*, a *Dutch* Phyſician, well ſkill'd in Antiquities and in *Greek* Poetry, being one of the Anatomical Society at *Amſterdam*, with *Blaſe*, *Quina*, and others. From the former of theſe two Lamellæ of the Pia Mater, namely, from the Arachnoides, is deriv'd the Tunica Choroides of the Eye; and from the vaſcular Lamella, or the Pia Mater, properly ſo called, ſeems to be deriv'd the Tunica *Ruyſchiana*, which lines the Choroides.

[2] Thus by receding from the middle of the Cornea, it leaves an intermediate Space, in which it fluctuates in the midſt of the aqueous Humour.

[3] A very fine Tunic which forms the Cells wherein the aqueous Humour of the Eye is contained, (See §. 528.) and confin'd in the Cells like a ſoft or conſiſtent Body.

[4] Thus it is called with reſpect to its internal Surface, but externally it is term'd the Iris; the Colour of which is various in different People, as grey, black, blue, *&c.* the latter is the external Surface of the Choroides, and the former its internal Surface. (See §. 520.)

[5] Nor yet do either the Choroides or Tunica *Ruyſchiana* form a compleat Circle or Sphere, but are in a manner perforated ſo as to leave a Foramen, which is denominated the Pupil.

[6] So called, as being demonſtrated by *Ruyſch* to be ſeparable from the Choroides, and ſpread with a different Series of Veſſels; for the Veſſels of the Choroides ſpread on all Sides like Rays from a Center.

§. 520.

§. 520. But while the Margin of the Choroides recedes and forms the Uvea, it receives *Nerves* [1] at the ſame time from thoſe which perforate the Sclerotica together with the Choroides, and being there communicated to the ſame, are divided into many ſmall Branches; from theſe Nerves and Membranes are form'd the exterior muſcular Fibres of the Uvea, tending from their Origin towards a Center, and terminating in a circular Ring compoſed of circular and muſcular Fibres, which determine the Figure and Capacity of the Pupil; and this circular Rim or Border which terminates the Pupil, being reflected back towards the Cavity of the Eye, becomes three times broader than it appears outward, and receives the internal ſtrait Fibres of the Uvea, and binds them together in the ſame manner; from hence it is evident that the orbicular Fibres contract, and that the longitudinal ones dilate the Opening of the Pupil; but the thin pellucid Membranes which connect the Fibres together, are covered over with a very black-colour'd Pigment on that ſide which is oppoſed to the back Part of the Eye.

[1] Betwixt the Choroides and Tunica *Ruyſchiana* run the Nerves, with the arterial, venal, and lymphatic Veſſels, together with aqueous Ducts; theſe Nerves run from the whole Circumference of the Choroides towards the Pupil, and form muſcular Fibres, which are inſerted into the Ring of the Pupil, like Rays tending to a Center from a Circle, ſerving to open the Pupil, by drawing its

Rim towards the more firm or fixed Part of the Choroides; theſe therefore admit Light more copiouſly, and increaſe the black Part of the Eye, while they diminiſh the colour'd Part of the Iris. This may be eaſily demonſtrated by Experiment in a Friend; for if you look at his Eyes expoſed to a ſtrong Light, the colour'd Part of the Eye which makes the Iris will appear as large as poſſible; and on the contrary, if you inſpect his Eyes in a dark Place, the Pupil will appear extremely large, and the colour'd Part of the Eye but very ſmall. The ſame Dilatation of the Pupil is alſo perceived in Twilight, or when the Light is ſo weak that it does not ſufficiently illuminate the Object. But theſe Fibres terminate in a Ring or Circle, which immediately encompaſſes the Pupil or Opening of the Eye, to which it is a true Sphincter, appearing much more diſtinct in the Eye of a Whale than in a human Eye. This Ring, which immediately encompaſſes the Pupil, being reflected inward, appears three times larger on the Side of the Uvea; for it is compoſed of two Planes, the one exterior in the Iris, and the other interior in the Uvea; but both theſe Rings, external and internal, contract the Pupil even to a very ſmall Point or Opening. The Uſe of this Sphincter or muſcular Circle, is to defend the Eye in too ſtrong a Light, by contracting the Pupil, and admitting fewer Rays; and thus it increaſes the colour'd Part of the Eye. Both theſe muſcular Rings have been lately diſcover'd by *Ruyſch*, afterwards by *Raw*, and ſince by *Hovius*.

§. 521. But in the Uvea there is alſo a wonderful Contexture of Arteries form'd into *Rings* [1], which from thence detach Branches, even

even though theſe Arteries, from whence thoſe Branches ariſe, formed before nearly the ſame wonderful Fabric in the Tunica Choroides. If now we conſider this wonderful *Apparatus* [2], it will teach us, that the greateſt Degree of Attenuation, muſt be here given to the moſt ſubtle Humours, and that the groſſer Parts of thoſe Humours are eaſily *retained* [3].

[1] As we find muſcular Fibres, which are ſome annular and others radiated, ſo there are alſo Veſſels both orbicular and branched out like Rays which accompany the muſcular Fibres; and theſe have been beautifully demonſtrated by *Ruyſch* and *Hovius*. Alſo together with the muſcular or nervous Fibres, the Arteries likewiſe are detached in Rays from that Part of the Sclerotica which unites with the Cornea, and from thence they tend towards the Pupil; and likewiſe wherever there is a muſcular Circle, there is another arterial one perpetually accompanying the nervous Fibres.

[2] Theſe arterial Ducts ariſe from the Arteries which perforate the Sclerotica in four Places, and appearing like black Points in the Choroides, they terminate in reticular Plexus's extremely minute; by which the Impulſe of the Blood is broke and its Particles attenuated, and at length being ſpread in the Tunica *Ruyſchiana* and Uvea, they ſeem to ſecern the aqueous Humour by open Tubes, ſome thouſands of times ſmaller than the leaſt Blood-Veſſels.

[3] The groſſer Parts are returned by Veins, which *Hovius* by his Injections has demonſtrated to open into the aqueous Humour, which is this way continually abſorbed.

§. 522. In the mean time that very thin *Membrane* [1] which forms the Uvea (§. 519.), ariſing from the Circumference of the Choroides in the ſame Place (§. 520.), is alſo furniſhed with arched muſcular Fibres, which embrace the riſing, gibbous, annular Surface of the vitreous Humour, where it projects beyond the Circumference of the cryſtalline Lens: the fixed Point of theſe muſcular Fibres is in the Beginning of that Circle of the Uvea round the Margin of the Cornea, from whence they ariſe; but their moveable Termination is in that Circle of the vitreous Humour which departs from the cryſtalline Lens. Theſe Fibres are more diſtant from each other than thoſe in the Uvea; their intermediate Spaces or Intervals being filled up with a *black* [2] Pigment or Colour: and here alſo there are Blood-veſſels found diſtributed in the ſame Manner like thoſe of the Uvea (§. 521.).

[1] From the Rim or Circumference of the Tunica Choroides and *Ruyſchiana*, where they depart from the Cornea, ariſes that very thin Membrane, a thouſand times finer, encompaſſing the vitreous Humour, but not covering the cryſtalline Lens. But from the Circumference of this thin Membrane ariſe nervous Fibres detached from the third and fifth Pair, and diſtributed like Rays on all Sides towards the cryſtalline Lens, being thoſe which the ancient Anatomiſts call the ciliary Ducts; whereas *Ruyſch* intends a different thing by that Name. By the Action of theſe Fibres the cryſtalline Lens is held firm or fixed in the

the ſame Place, and when they are contracted they may preſs back the vitreous Humour, ſo as to thruſt the cryſtalline Lens more forward, which will ſubſide again when theſe Fibres are relaxed. Theſe ſame Fibres continue on over the Margin of the cryſtalline Lens, to which they give that firſt or looſe Membrane which is ſpread upon its Fore-ſide. (See §. 503.)

[a] The internal Surface of the Uvea is ſpread with the very blackeſt Pigment, which prevents the Reflexion of any Rays from the outer Part of the Eye inwards; nor can any of the Rays paſs to the Retina, which enter the lateral Parts of the Eye; for theſe are on all Sides ſtopped or ſuppreſſed by the black Pigment; ſo that none can paſs to the Retina and extend their Action to the common Senſory, but what enter in a direct Courſe through the middle of the Pupil. If Nature had not furniſhed our Eyes with this black Pigment, the Mind would have perceived the external Figure of the Eye as in a Looking-glaſs, inſtead of the Image of each Object. The like Blackneſs was alſo ſpread betwixt the cryſtalline Lens and the Sides of the vitreous Humour, to prevent any of the Rays from being reflected back out of the Eye; for every Ray which falls upon the black Pigment is ſuffocated and abſorbed, and conduces nothing towards Viſion. Hence it is that any Perſon may ſee his own Face in the Eye of his Companion, where being depicted it is reflected back; but if this ſame Reflexion ſhould have ſucceeded within the Eye, the like Image would have been ſeen by the Perſon himſelf without inſpecting the Eyes of another.

§. 523. But the otherwiſe *flexible* [1] vitreous Body or Humour, is contained in a moſt fine

Membrane of its own, connected on all Sides to the concave Surface of the *Choroides* [2] by very minute Ligaments; being ſo ſlender or fine that it is ſcarce viſible, chiefly by reaſon of its extreme Pellucidity; yet this thin Membrane is perceptible, by the *diſtilling* [3] or dropping out of the Water, from the vitreous Humour, after it has been wounded.

[1] This vitreous Body is ſo flexible and free on all Sides, that when the Sclerotica is cut off, and an Inciſion made in the Choroides, it ſlips freely through together with its entire Membrane, without affording Signs of any manner of Connection. But it is improperly called a Humour, inaſmuch, as it is a firm but flexible Body, compoſed of thin Membranes and Muſcles.

[2] Theſe Ligaments from the Choroides are the ciliary Ducts, which ariſe from the Margin of the Choroides, in that Part where it forms the Uvea, and adhering to the whole Surface of the vitreous Membrane, they reſtrain the whole Body of it from collapſing into an aqueous Humour; they are on all Sides ſpread with a very black Pigment, and are called the ciliary Ligaments.

[3] The vitreous Body or Humour, as it is commonly called, being taken out of the Eye, and put into Water not quite ſcalding, floats and coagulates therein without diſſolving, and even without changing its Figure. If the ſame Body be taken whole out of the Eye, open'd by a very light ſharp Inſtrument, and then ſuſpended in the common Air over a glaſs Plate, upon wounding it with a Needle it will diſtil aqueous Drops continually, and the very thin Membranes remaining will by degrees quite vaniſh; the vitreous Body has therefore

fore a proper Membrane of its own, for otherwiſe it would have been diſſolved in the Water, if it was not defended with ſome Covering; it alſo appears to be made up of very thin concentric Sacculi, each of which is filled with its proper aqueous Fluid, but communicating altogether, ſince by wounding one of them all their contained aqueous Humour is diſcharg'd; for if the contained Liquor ſtagnated in one common Sacculus, it would then be ſuddenly diſcharged, upon making an Inciſion thro' the external Membrane, whereas we ſee that it diſtils very ſlowly. That this Membrane is furniſh'd with Veſſels is highly probable, only they are ſo thin and pellucid that they cannot be view'd even by the beſt Microſcope.

§. 524. In an Excavation in the middle of the lower and anterior Surface of the vitreous Humour is placed the cryſtalline Lens, free or moveable, and connected to the ſame by the vitreous Membrane (§. 523.) as well as by its own proper very thin *Membrane* [1]; but theſe fine Membranes with their contained Bodies are ſo thin and pellucid, that they are quite ſeen through; and yet Reaſon teaches us that they muſt be furniſh'd with their proper ſmall *Veſſels* [2]; and Experience demonſtrates the ſame in the largeſt of Animals, the Whale.

[1] The cryſtalline Lens is ſeated in a Cavity impreſſed in the lower Part of the Surface of the vitreous Body, and coheres to the ſame vitreous Body by ſmall Veſſels, which I have been able to diſcern with my Eyes, but of ſo tender a nature, that they are broke or deſtroy'd by a ſlight Preſſure of the Hand; but the Rim or Margin with which

which the cryſtalline firſt touches the vitreous Body, is encompaſſed all round with the ciliary Ducts, which form a Circle or Ring, as *Ruyſch* has demonſtrated by his Injections. From this ſame Circle of the ciliary Ducts is expanded a Membrane, which covers and contains the cryſtalline Lens, that it might not be eaſily ſhook or agitated in the vitreous Body; that the Capſula of the cryſtalline performs this Office, is evident in the couching of a Cataract, when the Capſula being inciſed, the cryſtalline Lens ſlips out of its place. The Surgeon ſkill'd in the Art of Couching, makes a Puncture thro' the Sclerotica, under or within the Rim of the Iris, at about the diſtance of the twentieth Part of an Inch from thence, or rather at the diſtance of two Lines from the Iris; as ſoon as the Sclerotica is perforated, and he ſees that his Needle can move freely, he then directs it in ſuch a manner as to avoid touching the Iris, until he perceives the Needle through the Pupil; when the Needle is ſeen thro' the Pupil, he then tries whether or no it adheres to or draws the Iris, and finding it free, he turns the Point of the Needle inward, and with a gentle Force wounds the anterior Membrane of the cryſtalline Lens, and forces out the Lens down to the bottom of the Eye. That this laſt Part of the Operation is neceſſary to be perform'd, they very well know who are ſkill'd in this Affair, whatever ſome of the Moderns may have wrote againſt this Opinion; for the Tunica Arachnoides of the cryſtalline Lens prevents it from ſubſiding on the aqueous Humour by its own Weight, which is greater than that of the aqueous Humour; this arachnoide Membrane covers the Lens before, and inveſts the vitreous Body behind.

The

[2] The cryſtalline Lens (which is a more juſt Denomination than that of cryſtalline Humour) is in Fiſh perfectly ſpherical; but in other Animals it is more or leſs flat or depreſſed, conſiſting as it were of two Segments of Spheres. If now the cryſtalline Lens of a human Eye is placed in warm Water, and you take off its Membrane by very fine Inſtruments, the whole Lens will appear diviſible into an infinite Number of parallel Strata, each of which are made up by ſmall Veſſels complicated in a particular manner; but each of theſe ſmall Veſſels are pervaded by their reſpective Humours, the Circulation of which is carried on even into the very Center or Body of the ſolid Lens. Theſe Veſſels ſeem to ariſe either from the ciliary Ducts, or from the vitreous Membrane. In the Eye of a Whale, the Rim of the cryſtalline Lens is encompaſſed with a hollow Ring or arterial Veſſel, from whence ſmall Roots are detached, even into the Beginning of the Lens. From hence it is evident, upon what minute Organs the Integrity of the Sight depends, which is one of the greateſt of human Enjoyments. For if the Eye continues ſound in other reſpects, and the Circulation of the Humours through the cryſtalline Lens only is diſturbed, that Body will then be continually obſcured with an Opacity, the Whiteneſs of which will be ſeen through the Pupil, ſo as to deſtroy or ſubvert the whole Sight.

§. 525. Laſtly, The interior *medullary* [1] Part of the optic Nerve, *perforated* [2] in its Middle, enters the Bottom of the Globe of the Eye in ſuch a manner, that its *Entrance* [3] with reſpect to the Height of the Globe, is in its *Middle* [4]; but in reſpect to the Breadth or

tranſverſe

tranſverſe Diameter of the ſame, the Nerve is ſeated one third Part of the Diameter of the Eye nearer to the internal Angle. Hence the optical Axis does not fall upon the Entrance of the optic Nerve, but recedes a conſiderable Diſtance from thence towards the external Angle. The Medulla of the optic Nerve being thus enter'd into the Globe of the Eye, is immediately after expanded in the Bottom of it under the vitreous Humour, ſpreading on all Sides together with the larger Arteries which enter'd with it, and accompany every Point of its Expanſion with their ſmall Branches; it has alſo *lymphatic Veſſels* [5], but in other reſpects reſembles a ſoft Mucus, and is called the Retina.

[1] The Pulp of the optic Nerve is compoſed of the Medulla from the anterior Ventricles of the Brain itſelf, or from the Thalami Optici continued into the Eye; at entering which, at the opening of each Globe, they depoſit firſt the Integument which anſwers to the Dura Mater, from whence it is derived to form the Tunica Sclerotica; it then depoſits the Tunica Arachnoides, from whence reſults the Choroides; together with the Pia Mater, from whence ariſes the Tunica *Ruyſchiana*. The Nerve being deſtitute of theſe Coverings, is then a naked Medulla or ſoft Pulp.

[2] This Perforation of the optic Nerve has been juſtly deſcribed by *Galen*, who is defended by *Euſtachius*, in oppoſition to *Veſalius*, whoſe valuable anatomical Tables ought to be purchaſed at any Price. *Galen* firſt deſcribes the nine Pair of Nerves, but ſays, that in the middle of the optic Nerve

Nerve there is a Cavity, continued as it were from the Eye to the anterior Ventricles. This Diſcovery of *Galen* was afterwards confirmed by *Ruyſch*, who eſteeming the Preparations of Art more than Books, was not acquainted with the Fame of *Euſtachius*. This Cavity in the optic Nerve is filled by a ſanguiferous Artery, which being empty in the dead Body is drawn back, and leaves a bare Tube or Perforation. From this Artery are derived the Veſſels which are diſperſed through the Retina and vitreous Humour. Upon this Perforation of the Nerve depends that wonderful Experiment of *Mariot*, which we ſhall mention hereafter at §. 542.

[3] When the optic Nerve has reached the Globe of the Eye, it is expanded on the internal Surface thereof, in medullary Rays or Fibres, and forms a true Membrane; ſo that the Retina is nothing more than the Medulla of the Brain itſelf expanded like a Membrane, that is, into a mucous Network. All this may be illuſtrated by Experiment in the Eye of an Ox; which ought to be taken entire out of the Orbit, and opening the Sclerotica by a crucial Inciſion, and then dividing the Choroides and Tunica Ruyſchiana, the next that follows to theſe is a tender Mucus, almoſt like that of the Noſe, of a whitiſh Colour, but little more conſiſtent than a Fluid, and capable of being deſtroyed by the leaſt Force. The convex Part of this mucous Membrane, the Retina, lies next to the Tunica *Ruyſchiana*, and its concave Part towards the vitreous Humour; betwixt which two it is expanded throughout the whole Cavity of the Eye, even to the ciliary Ducts, and almoſt to the Margin of the Iris.

[4] This Obliquity of the Inſertion of the optic Nerves ought to be well remember'd. For it is commonly ſaid by Anatomiſts, that the optic Nerve

Nerve enters the Middle of the Eye; and in ſome Animals this is true, but not in the human Body. We ought to ſuppoſe firſt a Plane to paſs through the Middle of the Axis of the Eye horizontally from before backward; and thus the whole Eye will be divided into two Parts, upper and lower. Now in this Plane the optic Nerve enters the Eye, in its middle with reſpect to upper and lower. But if we ſuppoſe the Eye to be divided by another Plane, deſcending perpendicularly thro' the former, the Eye will be divided into a right and a left half or Side: but then the optic Nerve does not enter the Eye in that Plane, but in the middle of the interior half of the Eye, ſo as to be one third Part of the Diameter of the whole Eye diſtant from the internal Extremity of the Bulb, and two third Parts diſtant from the oppoſite Side of the Bulb, next the external Angle of the Orbit; and therefore the Nerve recedes vertically, one ſixth Part of the Breadth of the Bulb of the Eye, from the Plane, which cuts the Eye perpendicularly into two Halves. The Reaſon of this Mechaniſm ſeems to be as follows. The Middle or Center of the optic Nerve is blind or inſenſible, becauſe there a conſiderable Artery enters the Eye; but the Artery cannot ſee, for the Nerves only are the Organs of Senſation. If you inſpect the Eyes of ſome Patients in a ſerene Air, there can be no ſenſible Defect obſerved, when at the ſame time the Patient complains of ſeeing little Balls dancing. This ariſes from the lymphatic Arteries which cover Part of the optic Nerve, and are not capable of ſeeing. This being the Fabric of our Eyes, had the optic Nerves been inſerted perpendicularly in the middle of the tranſverſe Plane, the parallel Rays coming from any Object placed before us, would have fallen upon this Artery; whence

whence we muſt conſequently either not perceive the Object at all, or elſe ſee it as with a Hole in the Middle. To avoid this Inconveniency, Nature has inclined the Entrance of the optic Nerves nearer towards the Noſe; and has thereby removed the blind Part of the Eye, ſo that it loſes only that viſible Point of an Object which is the leaſt neceſſary to be ſeen by both Eyes, and which may be always ſeen by one of them when there are two. Nor were the optic Nerves ever obſerved to deviate from this Obliquity of their Inſertion. But in the mean time it is to be obſerved, as we ſhall hereafter demonſtrate, in oppoſition to *Mariot* and others of the *French*, that not the Choroides but the Retina, is the true and immediate Organ of Viſion.

[5] *Ridley* obſerved lymphatic Veſſels in the Bottom of the Eye, diſtinct from the medullary Pulp of the Retina; which lymphatic Veſſels are pellucid, and incumbent on the ſenſible Nerve, in ſuch a Manner, that the Images of the Objects paſs through them as through a Glaſs. When any of the red Blood paſſes into theſe Arteries in Inflammations, the Eye is in a manner half blinded; and when they vibrate or beat, we ſee luminous Sparks in the dark. If a young Man is ordered to look towards his Noſe, and a Preſſure is then made upon the Eye, at the leſſer Angle of the Orbit, he will perceive a luminous Flame. Before an Apoplexy the Patient frequently perceives a luminous Flame or Sparks; and *Aretæus* obſerves, that the ſame Appearance precedes an Epilepſy. The like alſo is ſometimes obſerved in other inflammatory Diſeaſes of the Head, in a Phrenzy, *&c.* But when the Arteries are quite broke, a perfect Blindneſs follows, without any external Signs of the Diſorder, which is then called a Gutta Serena.

§. 526.

§. 526. The Cavity or *Chambers* [1] of the Eye formed before by the concave Surface of the Cornea, and behind by the convex Surface of the vitreous and cryſtalline Body, is *filled* [2] with a thin, very pellucid and *brackiſh* [3] Humour, inodorous, ſoon exhaling, and ſoon *renewed* [4], preſerving the flaccid Cornea equably *diſtended* [5] in its Convexity, ſupports on all Sides the *Uvea* [6] which is ſuſpended in it; and being extremely fluid in the time of Youth, it by Age paſſes through various Degrees of Thickneſs and *Opacity* [7], till at length it often becomes whitiſh in old People: it ſeems to *ariſe* [8] from the arterial Blood prepared in the Choroides, and more perfectly elaborated in the arterial Circles of the Iris, and in the vitreous Humour; and being farther attenuated in the ſmalleſt lymphatic Arteries which from thence ariſe, it continually tranſudes through open Ducts, ſeated all round the internal *Surface* [9] of the Cornea in the Iris, Uvea, vitreous Membrane and arachnoide Tunic of the cryſtalline Lens, opening into this Cavity; this ſame Humour is afterwards again continually *abſorbed* [10] by the open Mouths of the lymphatic Veins, without leaving any manner of *Fæces* [11] behind. For which Purpoſe of abſorbing, the Ducts of *Nucke* [12] and others are quite unfit, as will readily appear to any one after due Conſideration. This Liquor therefore, continually ſupplied by theſe *tender* [13] Parts or Veſſels, ſerves

ſerves continually to moiſten, lubricate and retain theſe Parts in their due State of Pellucidity; and even the Sinking or Collapſion of the Eyes in dying People, ſeems to infer that the ſubtle Spirits of the Nerves are alſo depoſited into this Cavity.

[1] Betwixt the concave Surface of the Cornea, and the convex Superficies of the vitreous Humour and the cryſtalline Lens, there is a Cavity, which is divided in the Middle by the Iris and Uvea into two Chambers, which communicate together by the Foramen of the Pupil. This laſt Cavity is quite filled full with the aqueous Humour. There are therefore three diſtinct Cells or Chambers in the Eye, like as there are three diſtinct Cavities in the Thorax. The firſt is the Chamber of the aqueous Humour, which is partitioned into two, the one anterior betwixt the Cornea and Iris, and the other poſterior betwixt the Uvea and ciliary Ligaments.

[2] So long as a Perſon lives, this Cavity remains full and diſtended with the aqueous Humour; but after Death it is continually waſting, and the Eye collapſes; inſomuch that the Eye ſeems to be diſtended to its proper Degree, by the continual pouring in of the aqueous Humour by the Vis Vitæ.

[3] This Humour is a little more conſiſtent than Water, is pellucid in a healthy State, freezes by Cold, though it is more difficultly turned into Ice than ſimple Water: it is in ſome meaſure ſalt or brackiſh, as I have frequently taſted. It congeals with Spirit of Wine; and therefore this Spirit ſeems to be improperly uſed in Diſeaſes of the Eyes.

This Humour is ſo ſoon renewed, that after extravaſating the ſame by a Puncture, it will be reſtored again in the ſpace of twenty-four Hours, as we are aſſured by Experiments. The Ancients were indeed not ignorant, that by perforating the Cornea, the aqueous Humour is diſcharged, and afterwards renewed again. This Obſervation was renewed by a ſome time famous Chemiſt, *Joſephus Burroughs*, a boaſting ſort of a Perſon, who periſhed in a *Romiſh* Priſon for writing againſt the Virginity of the bleſſed *Mary*. But he cloaked the Experiment under a Medicine, which he called the Quinteſcence of Celandine prepared by Chemiſtry; one Drop of which Eſſence being diſtilled into the Eye, reſtored the aqueous Humour and the Sight. He performed his Experiments before the Phyſicians at *Amſterdam*: He perforated the Cornea in a Dog, and ſuffered the aqueous Humour to be diſcharged, inſomuch that the whole Eye collapſed; and after dropping in this Liquor, bound up the Eye, and left the Animal in the Care of the Phyſicians. The next Day he undreſſed the ſame Eye in the Preſence of the Phyſicians, when it appeared full and fair like the other Eye, as if it had not been injured. But about the ſame time it was found by other Experiments, that the ſame Event would follow, even though nothing was poured into the Eye. The expert *Redi* tried the Experiment upon all Kinds of Animals, by wounding the Cornea near the Iris, and preſſing out the aqueous Humour, by which the Animal became blind: but by the Application of a Fomentation with Milk for forty-eight Hours, the Wound appeared healed, and the Eye filled with its aqueous Humour; whence it manifeſtly appeared that there are Ducts in the Eye, from whence the aqueous Humour is continually poured into

into its proper Cavity. There was a Lad of a noble Family, which at that time had the chief Government in the Republick, who in play had a Stone flung, by which the Cornea was wounded, and the aqueous Humour diſcharged, ſo that the Eye collapſed. I being called at that Inſtant of Time, order'd him to be bled plentifully, and to obſerve a perfect Abſtinence; and after dropping into the Eye ſome warm young Pigeon's Blood, without any other Quinteſcence, carefully bound up the Eye, and ſo left it for the ſpace of forty-eight Hours; after which time, in removing the Dreſſings, the Eye appeared entire and full, the aqueous Humour being perfectly reſtored. Upon this Experiment is founded that bold Operation of *Woolhouſe*, in which the Cornea is perforated to extract Matter or Membranes lodged in the aqueous Humour.

[5] The Eye would not be capable of ſeeing, unleſs the whole Cornea was equably diſtended and flexible outward; for the Eye can only be expanded into a Sphere, when the extending and reſiſting Forces are equable in every Point. This was therefore the Reaſon why Nature has extenuated the hard Sclerotica into the thin Cornea, and ſuſtained it by the aqueous Humour, which perpetually urges the Cornea forwards and outwards, by the vital Force with which it is impelled through its proper Ducts. For when that Force ceaſes, the Cornea continually ſhrinks or collapſes, the Colours of the Rainbow are obſerved in the Eye, and the whole Perſon becomes lifeleſs.

[6] When the Head is inclined forward, the Iris would approach towards the Cornea; and when the Head is inclined backward, it would approach towards the vitreous Humour, if it was not ſuſtained on each Side by the aqueous Humour: for by

this Humour it is kept in ſuch an Equilibrium, that there is no greater Inclination of it to one Side than the other, in all manner of Poſtures. If the aqueous Humour is deficient, as in People who are dying, in that Caſe the Figure of the Eye is changed, the Iris collapſes backward, and the Pupil dilates extremely large.

[7] When this Humour becomes opake, it forms the firſt Species of the ſpurious Cataract. In this Caſe the whole Eye appears whitiſh externally, and the Whiteneſs covers the Iris and the Pupil, ſo as to deſtroy the Sight, which can be reſtored by no Artifice; as we may often obſerve in old People. It is not difficult to diſtinguiſh this Diſorder from the true Cataract; for in this laſt, the Cornea and Forepart of the Eye, with the Iris, ſuffer no viſible Alteration, but a Whiteneſs appears behind the Pupil, namely, an Opacity of the cryſtalline Lens. If *Woolhouſe* had conſidered this Difference as he ought, thoſe who have wrote againſt him, with *Heiſter* and others, might very eaſily have reconciled the Difference of the two Kinds of Cataracts; namely, an Opacity of the aqueous Humour, and a Diſorder of the cryſtalline Lens. Laſtly, There is another Diſorder of this Humour when it is deficient, or not ſeparated in a due Quantity to ſuſpend the Pupil, which therefore collapſes backward.

[8] But as to the Origin of this Humour, it ceaſes to be any longer an Opinion or Conjecture, after it has been ſufficiently demonſtrated by Experiments. For all the Parts here mentioned are full of moſt minute Veſſels, the ſmalleſt of which ſeem to exhale a moſt thin Vapour, every Particle whereof is a volatile Spirit, and wonderfully expanſive; but being collected together and confined, theſe Particles are converted into a kind of

Water.

Water. Thus common Water is by the Force of Heat rarified into a Vapour quite volatile, and by the Force of Cold is again condenſed into a true Water: but we may fetch an Inſtance of this ſtill nearer in our Breath, which by the Cold is condenſed into aqueous Drops.

[9] The whole concave Surface of the Cornea, with the Convexity of the cryſtalline Lens and vitreous Body, together with the Surface of the Iris and Uvea. From this large Extent of Surface is ſeparated a thin Water, which continually moiſtens the moſt minute radiated and orbicular Muſcles of the Iris, and prevents their Concretion. And that the ſame Humour is ſecerned from the Cornea, we know by Experiment: for if the Eye-lids be held from winking, and the Cornea wiped dry in a healthy Perſon, ſoon after a thin Liquor will appear to tranſude through the dry Cornea. Thus *Peyerus* has demonſtrated by ſolid Experiments, that all the Membranes in the human Body perſpire.

[10] If this Humour was not to be abſorbed, being perpetually accumulated by the Arteries without returning by the Veins, it would cauſe a Dropſy of the Eye, or produce the Oculus Elephantinus, in which the Eye is diſtended forward in a very unſightly manner; but it is diſtended forward, becauſe behind there is the Reſiſtance of the bony Orbit, which obliges the accumulated Humour to exert all its Force in diſtending the Cornea. If the Cornea is perforated with a very ſmall Needle, the aqueous Humour diſcharges itſelf through the Puncture; but then the Water is ſoon renewed again, and the frightful Tumour of the Eye returns.

[11] It may perhaps ſeem wonderful to one, who duly conſiders that the Humours continue limpid

without any Opacity in the Eyes of a Perſon eighty Years old. But it is more wonderful to one, who conſiders that the aqueous Humour is opake in new-born Infants by a kind Proviſion of Nature, that their tender Eyes might not be moleſted, or too violently affected by the Light, to which they have not been accuſtomed. It is well known by every body, that Kittens and Puppies are blind at their Birth; but this is true not only in theſe Animals, but in all Animals in general; namely, that they are deſtitute of the Office of their Eyes. In the mean time, by degrees, the aqueous Humour depoſits its white Colour, and becomes more tranſparent, continuing ever afterwards limpid without depoſiting any Sediment, or forming any Spots; which is indeed wonderful, and not to be imitated in any other Humour.

[12] But *Hovius*, as well as *Nuck*, pretends to have diſcovered the true Sources or ſecretory Veſſels from whence the aqueous Humour is derived. It is ſufficiently demonſtrated from the Obſervations of thoſe Anatomiſts, that theſe Veſſels are at firſt large and ſanguiferous; but that from them ariſe other pellucid-Veſſels, from whence the aqueous Humour is derived after it has been attenuated in the Veſſels, paſſing through the livid Points of the Sclerotica and Choroides; and being afterwards farther attenuated and ſubtilized in the *Tunica Ruyſchiana*, it at length diſtils through the moſt minute aqueous Ducts. But ſo ſubtle a Humour could not poſſibly be ſeparated by any Veſſels but thoſe of the ultimate Series, or ſmalleſt decreaſing Arteries, which exhale their contained Juices. At leaſt we may be certain, that ſo long as we are capable of ſeeing theſe Veſſels, we are ſure that they cannot be the Fountains from whence the aqueous Humour is derived.

Namely,

[13] Namely, the very ſmall Muſcles of the Iris, Uvea and cryſtalline Lens, which require to be continually moiſtened in a Bath, leſt they ſhould concrete together, and become opake, and that they might continue conſtantly and equably flexible and free for Motion.

§. 527. The ſolid cryſtalline Lens, convex or *ſpherical* [1] on each Side, is compoſed of an infinite Number of fibrous, and very pellucid *ſpherical* [2] Strata or Segments, ſtrictly united to each other, ſo as to form a tranſparent *Body* [3] much denſer than the aqueous, or even than the vitreous Humour, which is ſeated in that Part of the Eye, where the Axis of Viſion paſſes through its Center, aſſiſting to form the ſame Axis, and lying nearer to the Cornea than the Retina, being made up of an infinite Number of ſmall Veſſels, as appears from the ſhrinking and Loſs of Weight which it ſuffers by *drying* [4]; it is therefore improperly called a Humour, ſince it is a Solid furniſhed with Veſſels from thoſe which are *continued* [5] to its including Membrane.

[1] The Surface of the cryſtalline Lens is perfectly equable; but when it is ſplit in two, it has unequal Sides, and multiplies Objects in the ſame manner as when we look through a Multiplying-Glaſs, which has many Sides or plain Surfaces, repeating the Image of a ſingle Object as often as the Lens is divided into diſtinct Planes. An Inſtance of this rare Diſorder has fallen under my own Obſervation.

[2] If the cryſtalline Lens be well cleanſed and held in ſcalding Water, there appears a white, fibrous and opake Cruſt upon its Surface; and if that be taken off ſlowly and carefully by a Needle, and viewed by a Microſcope, it appears to divide into an infinite Number of thin Membranes concentric to each other; but each connected to the other by a kind of reticular Plexus, as they riſe one under the other. Thus Children know how to peel off the opake Membranes or Coats from the white Eye of a boiled Codfiſh, till at laſt there remains a ſmall pellucid Spherule, which they call a Pearl.

[3] The cryſtalline Lens is in ſome meaſure render'd opake even by Death, but much more ſo by ſcalding Water. This is therefore the manifeſt and moſt frequent Cauſe of Cataracts, which ariſe from the Application of Medicines too hot for the Eyes, or from an Inflammation of the Eye preceding. For ſo ſoon as the cryſtalline Lens is opake, the Diſorder is termed a Glaucoma, which may be eaſily known from the Appearance of a white Spot in the Middle of the Patient's Eye, behind the Pupil.

[4] Thus *Hovius* experienced, that the cryſtalline Lens ſuſpended in the open Air contracted, and grew lighter every Moment, till at laſt it ſhrunk up to a dry callous Membrane. It is therefore repleniſhed with Veſſels, each of which are pervaded by their reſpective Humours. I made an Experiment for this purpoſe upon the cryſtalline Lens of a Hog: after abrading the firſt Membrane, a ſort of Liquor was diſcharged, which being wiped up with Lint, more Water followed in a leſs Quantity upon abrading the next Membrane, and ſo on.

Namely,

[5] Namely, thoſe continued from the Ring in which the ciliary Ducts terminate; which Ring was firſt demonſtrated to be vaſcular by *Ruyſch* in a Whale, whatever *Hovius* may ſay to the contrary; from which Ring an infinite Number of ſmall Veſſels paſs into the cryſtalline Lens for its Nutrition, and for conveying the Humours which continually circulate as long as we live.

§. 528. The vitreous Body or Humour is extremely pellucid, flexible, and more denſe than the aqueous, being *vaſcular* [1] on all Sides, as we are taught by the diſtilling and drying up of its Humour after wounding the Veſſels and including Membrane; and therefore there is doubtleſs a continual Circulation of its Humour. When the arched Fibres (§. 522.) are *contracted* [2], the Ring or Circumference of the vitreous Humour round the cryſtalline Lens is depreſſed, and therefore its Middle becomes elevated, and thruſts the cryſtalline nearer to the Cornea, and further from the Retina; but when theſe Fibres are relaxed, the Sides of the vitreous Body recover their former Situation, and the Swelling of its Middle ſubſides, by which means the cryſtalline Lens is brought nearer to the Bottom of the Eye to perform its proper Office. The vitreous Body is therefore ſofter than the cryſtalline Lens, that it might be ſuſceptible of this Change of Figure.

[1] We find that the vitreous Body grows up from that ſmall Bulk which we obſerve in the Fœtus, continually and equably augmenting on all

all Sides to that Magnitude which we obſerve in the Adult; whence it is evident, that it muſt be furniſhed with Veſſels, but which are ſo ſmall and pellucid that they eſcape the Sight. They ſeem to ariſe from the circular Rim, which has ſo many arterial Radii as there are Muſcles, which is demonſtrated to us by the Injections of *Ruyſch*: or it has Arteries or Veins which are pellucid from the Membrane of the vitreous Body which is incumbent on the Retina.

[2] The vitreous Body fills the whole Eye from its Bottom where the optic Nerve enters, even to the Backſide of the Uvea. It is convex on all Sides, and furniſhed in the Middle of its anterior Convexity with an Excavation or Cavity, into which the cryſtalline Lens is received; but round that Excavation there is a ſort of protuberant Ring. But the ciliary Ducts are ſpread upon the convex Surface of the Forepart of the vitreous Body, and are inſerted into its Membrane; and therefore when they contract or become ſhorter, they depreſs or thruſt back the vitreous Body on every Side. But behind there is the Reſiſtance of the bony Orbit; and therefore the vitreous Body will protuberate in that Part where there is the leaſt Reſiſtance, that is, in the Middle of its anterior Surface, which contains the cryſtalline Lens, and which is not compreſſed either by the Muſcles or the hard Sclerotica. It therefore follows, that the vitreous Body being preſſed back by the Contraction of the ciliary Ligaments, will thruſt the cryſtalline Lens forward towards the Cornea. And this is the Reaſon why the vitreous Body is more flexible than the cryſtalline: nor could the cryſtalline Lens itſelf be thus moved, if it was not more hard and denſe than the vitreous Body. There was the greateſt Neceſſity for this Mechaniſm

niſm in the Eye, to render it capable of ſeeing diſtinctly both near and diſtant Objects.

§. 529. The Eye thus formed (§. 515 to 529.) and ſeated in the bony *Orbit* [1], there receives in its Forepart the Tunica adnata, which is looſe, moveable, and derived from the Perioſteum of the external Margin of the Orbit; and this Membrane being pellucid and full of *Veſſels* [2], is ſpread over the whole anterior Surface of the Eye, the Bulb of which is by this means faſtened and ſecured without the leaſt Injury to its free Motion.

[1] This Membrane ariſing on all Sides from the Bones of the Orbit, appears white, and is ſpread from the Forepart over the whole Surface of the Globe of the Eye, covering the whole Sclerotica, and extending itſelf as far as the Iris, it there becomes very thin and pellucid, and is in that manner extended over the Cornea itſelf, as the exquiſite Anatomiſt *Amannus* demonſtrated thirty Years before, by ſeparating the whole Tunica adnata from the Sclerotica in the Eye of a Calf. There is alſo a Tumor of the Eye termed Hypopyon, or a Collection of Matter betwixt the Sclerotica and Tunica adnata; which laſt is in that Caſe to be punctured to diſcharge the Matter, and then the Diſorder may be cured in a little time. This Tumor ſometimes creeps or ſpreads over the Cornea, ſo as to demonſtrate apparently, that the Tunica adnata extends itſelf over the ſame. Nor yet does the firm Adheſion of this Membrane any way impede the free Motion of the Eye. It is therefore a falſe Notion which is commonly entertained, that the Tunica adnata terminates in a Circle,

Circle, as if it were cut off from the Cornea, which is ſuppoſed to remain naked.

[2] The Inſpection of the Tunica adnata leads us a great way into the Knowledge of Diſeaſes. When there is a ſmall or incipient Inflammation in the Brain, this Membrane always looks red; and therefore it may be uſeful to inſpect it with a magnifying Lens. We have now conſidered all the Coats of the Eye. The outermoſt of which is the Tunica adnata, after which follows the Sclerotica, which becoming pellucid in the anterior Part of the Eye, is there termed the Cornea. Under the ſecond or hard Coat of the Eye lies the Choroides with its interior Lamella, called from its Diſcoverer Tunica *Ruyſchiana*. But from the Choroides and Tunica *Ruyſchiana*, receding from the Sclerotica and Cornea, ariſes a ſixth Coat, namely, the Iris, the poſterior Face of which is called the Uvea. The eighth Tunic in the Eye is the Arachnoides, ariſing from the ciliary Ducts, and ſpread over the cryſtalline Lens. The ninth Tunic is that of the vitreous Humour ariſing from the Tunica *Ruyſchiana*. The tenth and laſt Coat is the Retina, namely, an Expanſion of the Medulla of the optic Nerve. We have alſo ſeen that the Eye is divided into three Cavities or Chambers; the firſt of which is partitioned into two, the one anterior and the other poſterior, containing the aqueous Humour betwixt the Cornea before, and the cryſtalline Lens behind, partitioned in the midſt by the Uvea and Iris, the former looking towards the Backpart of the Eye, and the latter towards the Cornea. The ſecond Cavity is that which contains the cryſtalline Lens, which may be conceived as a void Space, by ſuppoſing the cryſtalline Lens to be taken out. The third and laſt Chamber of the Eye, is that which contains the

vitreous

vitreous Body. So that all theſe Chambers or Cavities being abſolutely filled, there remains not the leaſt Vacuity in the whole Eye. The anatomical Demonſtration of the whole Eye and its ſeveral Parts, is owing chiefly to the Induſtry of thoſe, who have diſſected the Eyes of the largeſt Animals, as the Elephant and Whale, having firſt accurately injected its Veſſels, and then made a careful Diſſection of the ſeveral Parts, after the manner of *Ruyſch* and *Raw*.

§. 530. In the next Place there are four *Muſcles* [1], which ariſing *fleſhy* [2] from the Circumference of the larger Foramen in the Bottom of the Orbit, aſcend round the Bulb, about the Middle of which they become tendinous, and are in that Manner inſerted into the Sclerotica, to which they firmly adhere, and ſerve to *elevate* 3 or depreſs the Eye, draw it out or turn it towards the Noſe, fix it ſteady or turn it round, compreſs or elongate the ſame, according as they act either *together* 4 or alone; and conſpire with each other towards the ſeveral Motions of the Eye. Beſides theſe four ſtrait Muſcles of the Eye, it has alſo two oblique ones, the uppermoſt of which, the *obliquus ſuperior* 5, ariſes fleſhy from the lower Part of the Orbit near the Muſculus Atollens, and forming a fleſhy Belly in its Progreſs, it is at length changed into a round Tendon, which paſſing through a cartilaginous Pully in the upper Part of the Margin of the Orbit towards the Noſe, it paſſes back again from thence into the Orbit, and is inſerted

ſerted into the Bulb of the Eye, in the middle Part, betwixt the Entrance of the optic Nerve and the Inſertion of the Muſculus Atollens; and its Action is to turn round the Globe of the Eye about its Axis towards the Noſe, to draw it out of the Orbit, and at the ſame time to direct the Pupil downward, and by that means the Eye is ſo diſpoſed as to be capable of ſeeing things which lie near it in the Face, or upon the Noſe below itſelf. But the *obliquus inferior* [6] Muſcle ariſes fleſhy from that outer and lower Part of the Orbit, where the Bones are joined together, and is inſerted with its Tendon betwixt the abductor Muſcle and the optic Nerve; it ſerves to turn round the Bulb of the Eye towards the external Angle of the Orbit, to direct the Pupil the ſame way, and at the ſame time to turn it upwards, being capable of drawing the whole Eye out of the Orbit. But if both theſe Muſcles act *together* [7], they fix the Eye fierce and protuberant out of the Orbit, and render it capable of diſcovering any thing injurious that lurks near it; but by ſuſpending the Eye, they alſo render it very eaſily ſuſceptible of the Motions of the four ſtrait Muſcles. But we here likewiſe particularly meet with a Quantity of ſoft Fat, placed under the convex Part of the Sclerotica, and betwixt the Foramen of the bony Orbit, placed there for tranſmitting the optic Nerve, and to thruſt out the Muſcles from the Bulb of the Eye, and to a conſiderable Diſtance from the optic Nerve.

In

' In order to Viſion it was neceſſary either for the Eyes to be moveable, or elſe the Head muſt have been moved perpetually in looking about. Nature has uſed a threefold Mechaniſm in the Eyes; making them in ſome Animals moveable, and in others fixed, but aſſiſted by other means. There are ſome Animals which have their Eyes turning round as it were in the Extremities of their Shoulders or Arms, of which Kind is the Zygæna a frightful Animal of the Dog-kind, which from its terrible Aſpect is uſually called Meertefel, in which Creature the Eyes are not placed in the Head, but in the moveable Shoulders near the Head; and in hunting its Prey, theſe Eyes are elevated out of the Sea, and directed every way. Thus alſo Snails have their Eyes placed as it were upon their Horns as upon moveable Sticks. 2. There are other Animals again which have their Eyes fixed and immoveable, and in theſe the Eyes are very numerous. Of this Nature are Spiders, a very watchful Kind of Inſect, in whoſe Head or Back there are eight or ten immoveable Eyes. 3. There are others which have the Eyes fixed in a certain Part, but ſo as to be moveable by Muſcles, as we obſerve in moſt Kinds of Animals, and in ourſelves. But among this laſt Claſs of Animals, ſome are capable of thruſting the Eye out of the Orbit, and others are not at all capable of that Action. Among the firſt Claſs are all the horned Tribe of Animals; and among the latter are included the human Species. The horned Tribe of Animals have ſeven Muſcles belonging to the Eye, which occaſioned *Veſalius*, being deſtitute of human Bodies, to reckon a ſeventh Pair of Muſcles belonging to the human Eyes, which can be only found in Brutes. But we are here ſpeaking only of the external Muſcles

of

of the Eye, having before conſidered the internal Muſcles which dilate the Pupil, and contract the ſame, ſeated before in the Iris, and behind in the Uvea, as a Sphincter to the Pupil, to which add thoſe which move the cryſtalline Lens, namely, the ciliary Ducts or Ligaments.

[2] They are fleſhy in the back Part, but become tendinous forward under the Tunica Adnata, where they are expanded like Radii almoſt as far as the Cornea; that they are extremely moveable may appear, inaſmuch as they have Nerves from almoſt half of all the Pairs; for the ſecond Pair of Nerves ſerves for the Senſe of the Eye, but the third, fourth, fifth and ſixth Pair ſend Nerves for the Motion of the Eyes.

[3] The Muſculus Superbus elevates the Eye, the Humilis depreſſes it, the Indignatorius draws it from the Noſe, and the Bibitorius draws it to the Noſe; which Muſcles continually operate, and keep the Eye in a Plane parallel to the Noſe, unleſs there is ſome Blinking or Defect in the Eye.

[4] When all theſe Muſcles act together with an equable Force, they draw the Eye into the Orbit; but as they all belong to the Sclerotica, and do not extend to the Cornea, it follows, that this laſt will remain unmoved, while the reſt of the Globe of the Eye is drawn inward; and by that means the whole Eye will be in ſome meaſure elongated, to render it capable of ſeeing Objects which are very near to it. *Perrault* indeed wonders how four Muſcles placed round a Sphere diſtended with Liquor, can preſs it ſo as to change its Figure and render it longer. It muſt be confeſſed indeed that this Change is but ſmall, but yet the Cornea ſeems to be changed into an Arch of a leſſer Sphere, accommodating itſelf ſo to the Eye, as to give a greater Refraction to the Rays.

The

[5] The Obliquus ſuperior or Trochlearis Muſcle, ariſing from the Bottom and internal Surface of the Orbit, near the Origin of the Superbus, aſcends over that laſt Muſcle, and inclines towards the Noſe and lateral Part of the Orbit, (but not towards the Middle of the Side of the Orbit like the Recti Muſcles) where there is a ſmall Notch perceptible in the Margin of the Orbit, and paſſing through a cartilaginous Ring, it is from thence reflected obliquely backward into the Orbit, and inſerted in the Middle of the upper Part of the Globe of the Eye, betwixt the Entrance of the optic Nerve and the Muſculus atollens. When this Muſcle acts alone, it draws the middle and upper Part of the Globe of the Eye forward out of the Orbit, and upward towards the Noſe, and at the ſame time it turns round the Eye about its own Axis; ſo that it ſeems to change the extreme Point of the Axis of Viſion, and turn it towards the Noſe. Its Action is therefore, 1. To draw the Eye out of the Orbit towards the Noſe. 2. To turn the ſame round about its Axis. To this Muſcle is ſent the whole fourth Pair of Nerves. There was a certain epileptic Patient, who always ſaw Objects double, becauſe this Muſcle was paralytic, and overcome by the ſtronger Power of the abducent Muſcle.

[6] The lower oblique Muſcle is leſs than the former, but broader. It ariſes from the outer and lower Part of the Orbit, or from the internal Angle at the Bottom of the Orbit, where the upper Jaw-bone joins with the Side of the Orbit, ariſing fleſhy from a Cavity there of its own, perceptible by the Finger in a dry Skull; and then entering the Orbit, it proceeds obliquely to the middle and bottom Part of the Globe, and is inſerted betwixt the abducent Muſcle and the optic Nerve. It

draws the Eye towards the poſterior and lower Part of the Orbit outwards, and turns the Pupil upwards and towards the Noſe; that is to ſay, it turns the Eye round upon its own Axis, and at the ſame time draws it out of the Orbit towards the Noſe, ſo as to render it capable of ſeeing the Eyebrow above the Noſe. And this is the proper Uſe of this Muſcle when it acts alone.

7 When both theſe Muſcles act together, the one of them draws the Eye out of the Orbit downward, and the other upward; by which means theſe Muſcles deſtroy the Action of each other, as far as they are Rotators of the Eye, by their acting in a contrary Direction; at which time they exert all their Force in drawing the Eye outwards, ſo as to render it protuberant: by this means therefore they render the Face fierce, terrible and cruel, which Painters well know, as they expreſs theſe Paſſions of the Mind by ſuch a turgid Poſition of the Eyes; and which we ourſelves conſtantly perceive in People who are in a Rage with Anger, and eager after Revenge. 2. Alſo when theſe Muſcles act together, they draw the whole Eye towards the Noſe, that it may be better able to diſtinguiſh Objects. This Action is alſo obſervable in thoſe who are fighting or ſtriving for their Lives, as in Duelling, when each is very intent upon the Motions of his Antagoniſt. But when the recti Muſcles of the Eye act together, we do not ſee near Objects. 3. *De la Hire* well obſerves, that the Eye of a Perſon or other Animal in a great Fright is fixed protuberant out of the Orbit, ſo that the Eye may be eaſily determined towards any Part which is intended to be obſerved by the Action of any of the recti Muſcles. The ancient Statuaries very well expreſſed this Action in their Figures of *Lycaon*. This Action of the oblique Muſcles is

ſo

ſo manifeſt from their anatomical Structure, that one would wonder how ſome Gentlemen of Note can in the leaſt doubt it.——In the human Species, the Action of theſe Muſcles is ſufficient; but in the horned Tribe of Animals which feed from the Ground, the whole Bulb of the Eye is in a manner contained in a muſcular Caſe or Shell, which makes the ſeventh Muſcle of the Eye; by the Contraction of which, the Eye is thruſt foward out of the Orbit. And this Action of the Eye we obſerve in the Ox, when he is enraged and threatens an Attack, while his Head is depreſſed and his Tongue licks the Ground; for he then thruſts out his Eyes almoſt a Finger's Breadth out of his Head, and continually taking Aim, ſtrikes and levels his Enemy with a greater Certainty by his Horns. In *Spain* there are frequently Bulls fought with Men, who having received their Pardon enter the Ring, and approach towards the enraged Bull: and here the Champion places all his Safety in obſerving the Eyes of the Beaſt; for as ſoon as he perceives them begin to protuberate, he leaps on one Side, and ſtrikes his Dagger betwixt the Horns of the Bull, who by that means falls a Victim. This ſame Muſcle fixes the Eye ſteady in Brutes, that they can look longer upon the ſame Object. *Veſalius* has falſely deſcribed this Muſcle, as if it belonged to the human Eye; and, what is worſe, he endeavours to defend it againſt *Fallopius*. Laſtly, In Birds whoſe Eyes are placed in their Head laterally, and who ſcarce at all look directly downwards towards their Beak, there is a like muſcular Caſe, which thruſts out the Eye that it might look directly downward towards the Beak, ſo as to diſcern their Food or Prey. But this in Man is performed by a ſlight Motion of the Head. Otherwiſe the Eyes of Birds are fixed, and cannot turn

every way; whence they are obliged to be continually turning their Head about towards the Object at which they look, or towards their Prey, after which they are in ſearch. In the Facies hippocratica, the Fat being all conſumed in the Orbit, the Eyes are ſunk and rigid, inſomuch that the Patient is obliged to turn his whole Body towards any Side or Object at which he looks.

§. 531. But in order to determine the Manner and Seat of Viſion, it will be neceſſary for us to add to this Structure of the Eye, (§. 508 to 531.) what is demonſtrated to us in this reſpect by the Principles of *Optics* [1], *Dioptrics* [2], and *Catoptrics* [3]; a Compendium of which we are therefore to introduce here, chiefly from Sir *Iſaac Newton* [4], whoſe deep Penetration in mathematical and philoſophical Matters, ſeems to have exceeded the utmoſt Limits of human Underſtanding.

[1] Optics is that Part of experimental and mathematical Philoſophy, which teach us the Laws by which the Rays of Light ſpread from a radiant Point, or are reflected back from an opake Point, or elſe paſs through an homogeneous Medium. It may be termed the Doctrine of Viſion in its greateſt Extent. But by mathematical or experimental Philoſophy we underſtand, that which leads us to the Knowledge of Bodies by Experiments.

[2] Dioptrics is that Branch of the Science of the Viſion, which teaches the Laws by which the Rays of Light paſs through pellucid Mediums of different Denſities, and are changed in their Courſe by thoſe Mediums. It is ſo called from Dioptron, a Hole to look through.

Catoptrics

[3] Catoptrics is that Part of the Science of Viſion, which teaches us the Laws by which the Rays explained by Optics fall upon an opake Body, and are from thence reflected ſo as to form the Image of the Object. It is ſo called from Catoptron, a Looking-glaſs.

[4] Before Sir *Iſaac Newton*, all the Writers of Optics were in an Error; and although Authors pronounced that Colours were inherent in Bodies, yet none ſufficiently explained the thing: but Sir *Iſaac Newton* firſt ſtepped out of the common Road, and conſidered Light in itſelf, and Colours as contained in Light, with their ſeveral Compoſitions and Diviſions; all which he has compriſed in that for ever to be eſteemed Volume, his *Optics*.

§. 532. *Light* [1] being an *aggregate* [2] or Mixture of all Colours, *every way* [3] diffuſes its *Rays* [4], which are extremely *ſubtle* [5], but yet are *compounded* [6] of all Sorts of Colours; hence therefore Light is diviſible into ſeveral ſimple Colours, which being collected together or ſeparately, make various other Colours, but being all combined together form a moſt ſplendid Light or Brightneſs like that of the Sun: and theſe Rays come from a lucid Point as from a Center, and ſpread from thence in right Lines through an uniform Medium towards every Point, paſſing through pellucid Bodies at the ſame time, and all in an inſenſible *Space* [7] of time; but they ſtrike againſt and are reflected from opake Bodies, ſo as to return from every Point towards the Cornea of the Eye in the Shape of a Cone, whoſe Apex is the lucid Point, and its Baſis the Cor-

nea itſelf, provided there is no Obſtacle interpoſed betwixt the lucid or radiant Point and the Cornea.

1 Light is an Aſſemblage of ſmall Particles emitted to the Eye from lucid Bodies, by which we are enabled to ſee them and other things. If the Sun only was abſent, and all the other Bodies in the Univerſe were to remain the ſame, the Eye however well formed, would not be capable of diſcerning any thing. Light we therefore call that Body ſo little known to us, which enables us to ſee, being the ſame with regard to us, whether it comes from the Sun, the Moon, a Candle, Fire, or the like.

2 A Colour is ſomething ſeen by Light, for we can ſee nothing which has not ſome Colour. Viſion is therefore Light, and Colours are the Species or Kinds of Light. *Euclid*, the Prince of thoſe Philoſophers who ſearch after true and diſtinct Notions of Things, well defines a Surface to be the apparent Face or Limits different from the thing itſelf; ſo that we ſee nothing of the real Object. Colour is therefore the Image of the thing ſeen, and Light an aggregate of all that is viſible in the Univerſe.

3 If all the Walls and Roof of a dark Place are filled with Eyes capable of ſeeing, and then a Light is placed in the Middle of the Chamber, all thoſe Eyes will ſee the Light, and at one and the ſame time. Therefore the thing which is ſeen ſpreads itſelf every way upon the ambient Surface of the Object. Let there be a very ſmall red Spherule in a Chamber, every one preſent will ſee the ſame Sphere, and yet no one will ſee the ſame Rays which the other ſees, but each will receive a diffe-

rent

rent Portion of the Sphere of Rays which are ſent towards him. Hence therefore the viſible Rays or Images of Objects are ſpread from them equally on all Sides.

[4] By the Name of Rays we term thoſe Images of Objects which are infinitely diviſible.

[5] Let there be a Place extremely dark, in the Wall of which fix a thin Plate of Gold, perforated by the Point of the ſmalleſt Needle; and to this Aperture within-ſide, let the Eye be applied in its healthy State, it will in that Caſe ſee as diſtinctly the Trees, Houſes, and other Objects, as if it was placed in the open Air: and therefore all the viſible Points from ſo many and ſo different Objects, paſs through ſo ſmall an Aperture. Hence therefore the Rays of Light exceed in Subtlety even the Power of Imagination itſelf.

[6] All Philoſophers have allowed what has been hitherto ſaid concerning Light. But we now come to thoſe Properties which have been diſcovered in Light by Sir *Iſaac Newton*; namely, that Light is not a ſimilar Body, as was commonly ſuppoſed; but that each Ray of Light is compoſed of ſeven other Rays, which joined together form a ſplendid or ſhining Point or Spot, a thouſand times brighter than Whiteneſs, ſuch as ariſes, for Example, from the Deflagration of Nitre with Sulphur. But when ſuch an entire Ray of Light is ſplit, it ſeparates into ſeven diſtinct Rays; one of which is Red, the other Orange-coloured, the fourth Yellow, the fifth Green, the ſixth Blue, and the ſeventh Violet; namely, the ſeven primitive Colours: all which were preſent in the ſingle Ray of Light, but by falling upon different Objects are ſeparated from each other, and produce different Colours. But from the Combination of theſe primitive Colours ariſe an infinite Number

of mixed Colours, according as the firſt is combined with the ſecond, third or fourth, or the ſecond with the third, fourth or fifth, *&c.* From theſe ſeven diſtinct Rays therefore many thouſands of Colours may ariſe barely by combining them in all manner of Rays. Theſe ſimple Rays, as they are ſuppoſed to be, may be yet ſimple only as to Senſe, and in reality compounded of other more ſubtle Rays, from whence again may properly ariſe an infinite Diverſity of Colours.

[7] When the Rays of Light paſs through a Medium perfectly tranſparent, and without any Reſiſtance, they paſs on abſolutely in a right Line, inſomuch that the Rectitude of every thing is judged of by the Line of Sight. But in the Atmoſphere the Rays of Light do not paſs on in a right Line, as they proceed through a rarer Medium above to a more denſe Medium below, whence it is that the Rays of Light are variouſly inflected in the Air. Yet we call them ſtrait Rays which enter the Eye in a right Line from the Object, whence they were laſt reflected. Through the ſame uniform Medium, theſe Rays paſs through an infinite Space in the ſmalleſt Interval of Time. For what is objected by the celebrated *Danus* againſt the immediate Continuity of Light from the *Satellites* of *Jupiter*, is ſince found to be without Foundation by the later Experiments of *Caſſini* the younger. But we are convinced of it by a more ſimple way of reaſoning, for we immediately perceive the Stars as ſoon as we open our Eyes, notwithſtanding they are ſo many thouſand Semidiameters of the Earth diſtant from us. It is an aſtoniſhing Argument of the Divine Wiſdom, that we ſhould thus be made capable of perceiving the Stars, though ſeparated from us by ſuch an immenſe Diſtance. But with reſpect to hearing

the

the Laws are very different; for no Creature would be capable of any Reſt or Silence, if Sounds were not required to paſs through a determinate Space to us, in order to be heard. Nor is it ſufficient to turn the Head aſide, in order to exclude Sounds; nor can we ſo eaſily cloſe our Ears as our Eyes, which are ſo contrived, that we can admit more or leſs Light at pleaſure.

§. 533. The ſame Rays of Light approaching near to more denſe Bodies, are *incurvated* [1] or turned out of their direct Courſe, ſome more and others leſs; and thus they are *ſeparated* [2] from each other, reflected back to the Eye, and give the Senſe of different Colours which are falſely aſcribed to the reflecting or refracting Bodies, any farther than as the Surfaces of thoſe Bodies ſeparate the different coloured Rays from each other. This *Reflexion* [3] is therefore various, according to the Variety of Colours in the Rays of Light itſelf; but yet in their Reflexion the Rays return in the ſame reflected Angle as that of their Incidence, with regard to a Perpendicular erected at their incident Point, nor is there any other Alteration here perceived.

[1] When the Rays of Light paſs from a rarer Medium to a more denſe Body, they are attracted by that Body by the great Providence or univerſal Law of Nature; for without this Property of Light we ſhould be capable of ſeeing nothing but lucid Bodies. But the Rays are attracted moſt, when they are neareſt to the virtual Surface of the Body itſelf. If the Rays of the Sun were attracted

ed by the Earth, as ſoon as ever they were ſent out from the Sun, there would ariſe an incorrigible Confuſion in our Atmoſphere, nor would there be any ſuch thing as a right Line. This Attraction we know is performed, 1. Towards all denſer Bodies, to which the incident Rays are more or leſs incurvated. 2. Towards every inflammable Body. 3. Towards certain diaphanous Bodies, ſuch as Iſland Cryſtal.

[2] In reality we neither ſee the Body nor its Surface, only the Rays which return from the Body: but the different Surfaces of Bodies occaſion one kind of Rays to be reflected more than another; and thus ſcarlet Cloth bears that Name, becauſe it reflects only the red Rays, while the other ſix Kinds of Rays are abſorbed. Light itſelf cannot therefore produce the Diverſity of Colours, ſince it is moſt equally diſtributed to all Bodies.

[3] Let a Perpendicular be raiſed upon the plain Surface upon which the Ray falls, and let the Ray fall upon the Surface in an oblique Line, that Line with the Perpendicular will form an Angle: in the next place, let the Ray be reflected back; in that Caſe the Angle of Reflexion intercepted betwixt the oblique and perpendicular Line, will be equal to the Angle of Incidence. But when a Ray falling upon any Body is reflected back from thence to our Eyes, it ſeems to the Mind as if it came from a Point as remote as the Body from whence it was firſt emitted. I have frequently taken ſome Pains to explain this Appearance. Let there be a plain Speculum ſeated at the Diſtance of ten Feet, the coloured Image of the Object will fall upon the Surface of the Glaſs, without paſſing through; becauſe behind the pellucid Glaſs there is an opake Lamen or Leaf of Mercury, which reflects the Image to the Eye; in that Caſe the Mind

Mind judging in its uſual manner concerning the Diſtances of Bodies, will ſee the Image as if it was at the Diſtance of twenty Feet, with the ſame Senſe of Space or Diſtance, as if the Image had paſſed on through the Glaſs to the Diſtance of ten Feet behind in a right Line. If you ſee the Image of a Tower in a Speculum a Mile diſtant, it will appear in the Glaſs as if it was a Mile behind the ſame. It is therefore a conſtant Law, that we ſee coloured Objects repreſented as if their Diſtance was continued in a right Line.

§. 534. But if theſe Rays paſs out of *one Medium* [1] into another, they are incurvated at their Approach near to the latter, and then they continue on in a ſtrait Line through the ſame Medium: and thus are the Rays incurvated more towards the Perpendicular, in proportion as the latter Medium or Body is more denſe, and the more do they diverge or recede from the Perpendicular in proportion as the Medium or Body is more rare; excepting that Difference which ariſes from a particular and latent Cauſe in ſome certain Fluids, no otherwiſe diſcoverable than by Experiments. This Incurvation of the Rays, either to or from the Perpendicular, is called their Refraction.

[1] So long as the Rays paſs through an uniform pellucid Medium, they receive no Alteration in their Courſe, nor is there any Cauſe to change their Direction. They would therefore go on *ad infinitum*, in the ſame Line of Direction, as they came in from the radiant or reflecting Point: but when the Medium which it enters is more denſe, the

the Ray is then drawn more towards the Perpendicular, than in a rarer Medium; and this more in proportion as the ſecond Medium is more denſe than the firſt. Thus if a Piece of Money is placed in the Bottom of a Drinking-pot, in ſuch a Manner that the Margin of the Pot juſt conceals the Money; if then the Pot or Mug is filled with Water, the Money will by that means appear viſible to the Eye, though held ſtill in the ſame Place, and ſeem as if it was raiſed by the Water. For in this Caſe by pouring in the Water, the Rays diverging from the Money, are collected more together towards the Perpendicular or Point, which Geometricians eaſily determine, and call the Focus; but this is found from the Nature of the given Curve, in which the Ray falls; for by that means the Denſity of both Mediums may be known.

§. 535. But this Refraction of the Rays as to Senſe, is conſtantly performed agreeable to the following Rule: namely, if the ſame Ray falls into the ſame tranſparent Medium, at different Angles of Incidence; then the Sines of the Angles of Refraction will be to each other, as the Sines of the Angles of Incidence.

§. 536. Hence therefore the Rays coming from the radiant or reflecting *Point* [1] to the pellucid *Cornea* [2], are there *refracted* [3] towards the Perpendicular, almoſt in the ſame Manner as if they entered into *Water* [4]; and thus they go on through the aqueous Humour, by which means they are *determined* [5] to paſs thro' the Foramen of the *Pupil* [6], ſo as to fall upon the Surface of the cryſtalline *Lens* [7]; but thoſe Rays

Rays which entered the Cornea ſo *obliquely* [8], as to fall upon the Iris, are reflected back again out of the Eye, leſt being reflected and entering the Eye, they ſhould cauſe undiſtinct Viſion: and even the other Rays which by their Obliquity fall betwixt the Uvea and *vitreous Body* 9, upon the Surface of the ciliary Ducts or lower Part of the Uvea, are then ſuffocated in the black Pigment which is there ſeated, in the ſame manner as if they had never entered; and thus no other Rays can paſs through the vitreous Humour, but what have firſt entered through the Pupil, and fallen upon the Surface of the cryſtalline Lens. In the mean time the Iris being *contracted* [10] or dilated, admits more or fewer Rays, as the Object is more vivid or illuminated, and nearer to the Eye, or more languid and remote, with this Difference, that the more luminous and the nearer the Object, the ſmaller the Pupil, and the reverſe; and thus is formed the Machine of the Eye deſcribed (§. 520.), which defends the tender Retina from being injured, dried up or burnt by the Rays of Light.

[8] This Point is a lucid Spot, which is as a Center to the Rays, which are diſperſed from thence into a Sphere of an infinite Diameter. When theſe Rays of Light fall obliquely upon an opake Body, they are reflected back in an Angle, equal to that in which they fell upon the reflecting Body. If they fall in a right Line, they will turn again in the ſame direct Courſe; or if they make an Angle with the Surface of the reflecting Body, they

they will return from it in a like Angle. That Point of the Body upon which the Rays fell, and from whence they return, is called the reflecting Point, and has the ſame Properties or Affections with the radiant Point. For Example, let the Sun be the radiant Point, then the Surface of a Speculum or Mirror, upon which the Image falls is the reflecting Point. For the reſt, this whole Matter ſeems to have been treated in the beſt Manner by the celebrated *Huygens*, in his ever to be eſteemed Book of *Dioptrics*, as alſo by *Barrow*, in his *Cantabrigian* Lectures.

[2] The Cornea is extremely pellucid, upon the Surface of which the diverging Rays fall from the radiant or reflecting Point, as many of them as can be contained in a Cone, whoſe Baſis is the Cornea, and Apex the radiant Body. This follows from the equable Motion, with which Light in general is diſperſed by Rays from the lucid Center, every way in a Sphere.

[3] But when theſe Rays have reached the Cornea, they begin to be ſtrongly attracted towards the Center of the more denſe Medium, by which means they converge or run towards each other.

[4] The Cornea has near the ſame Denſity with Water, and therefore it refracts, or cauſes the Rays paſſing out of the Air to approach each other in the ſame manner as if they entered Water.

[5] The Rays of Light which paſs in a right Line through the Middle of the Cornea, go on in the ſame right Line to the Bottom of the Eye. The other Rays converge, and though they diverge in the Air, yet after paſſing through the Cornea, they are drawn towards the Center, in proportion as the Cornea is more denſe than the Air. But the Figure of the Cornea is ſpherical, or rather inclining

inclining to a Sphere, from which it deviates in ſome meaſure, being a Segment of a leſs Sphere than that of the Sclerotica; for the Figure of it depends upon the Humour extending the Cornea, as a flexible and elaſtic Plane. But this Expanſion by the Humour is not perfectly equable, ſince the aqueous and vitreous Humours gravitate more downward than forward, almoſt in all Poſitions of the Eye; whence the Cornea becomes flatter than it ought to be. Other expert Opticians pronounce the Cornea to be of an hyperbolical Figure; but it would be very difficult for them to demonſtrate that Figure which they ſeem to have invented in their own Imaginations: but it will be beſt for us to admit the Cornea to have almoſt the ſame Properties with the Sphere, and therefore to place the Focus of the Cornea behind, at the Diſtance of a Semidiameter behind the greateſt Convexity of the Cornea. The aqueous Humour does not alter the Refraction, ſince its Denſity and Pellucidity are agreeable to that of the Cornea.

[6] The Foramen of the Pupil is leſs than the Cornea, and ſeated behind that Membrane; and yet it receives almoſt the ſame Number of Rays with the Cornea, becauſe they were by this laſt render'd converging, by which means a greater Number of Rays are admitted to the Bottom of the Eye, than if it was not provided with the Cornea, and they were to paſs on converging through a leſs Space to their Focus at the Bottom of the Eye. Without this Refraction, but very few and only parallel Rays would paſs to the Retina, while thoſe Rays which fell upon the Iris would be reflected back again out of the Eye.

[7] The Rays of Light which the Cornea refracts towards its Focus, are all carried to the cryſtalline Lens. This is a Segment of a leſs Sphere than the

the Cornea, as may be eaſily known or demonſtrated by comparing the Lens with the diſtended Cornea in a living Perſon. Upon this Lens fall thoſe Rays which were rendered converging by the Cornea, and which are here again refracted and collected into a Focus. Nor are the Rays much more converged or refracted in paſſing through the cryſtalline Lens, notwithſtanding that is more denſe and ſpecifically heavier than the aqueous Humour; nor can I by any means think that the Refraction is ſo much increaſed by the Cryſtalline as *Huygens* believed: only the Figure of this Lens being a little more ſpherical, cauſes an Alteration in the Courſe of the Rays; to which we may add its ſmall Degree of greater Denſity. The cryſtalline Lens is in general a little ſmaller than the Cornea; nor can the cryſtalline Lens by any means be formed larger than the Cornea, becauſe the whole Margin of the Lens is ſpread with a very black Pigment, by which thoſe Rays are ſuffocated which fall upon the lateral Parts of the Lens.

[8] The Rays of Light which fall in a too oblique Direction upon the Surface of pellucid Bodies, are not tranſmitted through, but reflected back from them. Thence the Sea-water which appears black at Noon, reflects the Brightneſs of the Sun both at its riſing and ſetting: but when the Sun is riſen higher above the Horizon, ſo as to ſend its Rays perpendicularly, they are then tranſmitted into the Water, without any of them being reflected; but when the Sun is near the Horizon in a Morning or Evening, its luminous Rays falling obliquely upon the Water, are reflected with ſo great a Brightneſs to the Eyes of the Spectator, that it is not without Injury to his Sight that he can behold them. Thoſe Rays therefore which fall too obliquely through the Cornea, are reflected from

from the cryſtalline Lens; and as the Angle of Reflexion is equal to the Angle of Incidence, they will fall upon the interior Part of the Uvea. If now the Uvea was pellucid or white, it would a ſecond time reflect the Rays again, ſo as to make them fall upon the Retina, and diſturb the diſtinct or true Image of the Object which is neceſſary to perfect Viſion. Hence therefore Nature has covered the internal Surface of the Uvea with a very black Pigment, in which all the oblique Rays are abſorbed, that none of them may paſs to the Retina, but what go on in a right Line through, and refracted by the cryſtalline Lens.

9 The vitreous Body differs but little in Solidity from the cryſtalline Lens, being a ſmall matter ſpecifically heavier than the aqueous Humour. It is ſeated in the Back-part of the Eye, with the cryſtalline Lens in the Middle of its Fore-part, and the ciliary Ducts on the Sides; and therefore the Rays are not altered in their Courſe through the vitreous Body; and the leſs, when the ciliary Ducts being contracted, preſs back the vitreous Body ſo as to render it a little more compact or ſolid. They ſeem to produce this Action, whenever the Rays require a greater Refraction, to direct them into a certain Focus. For if the vitreous Body becomes but a little more ſolid, the Focus will be conſiderably changed.

10 Aſk a Friend, or rather a fearful Child, to look with his Eyes towards a clear Light, and you will then perceive the whole Eye appear coloured either with Blue, Grey, Cheſnut, *&c.* while the Curtain of the Pupil at the ſame time contracts almoſt to a Point. Afterwards order the ſame Perſon to look attentively at a Piece of Money placed in a Hat, in order to diſtinguiſh the ſame; you will then perceive the Pupil continually

nually dilate, till it is ſo large as to make the whole Eye appear black, except the Tunica adnata. Nature has provided this wonderful Mechaniſm in the Eye, to defend the Retina from being burnt up by too great a Quantity of Light, falling ſuddenly into the Eye. For a Perſon may become ſuddenly blind by looking ſtrongly at the ſcorching Noon-Sun in the Summer-time; which kind of Blindneſs is frequent among the *Chineſe*, who from a religious Superſtition, follow the Courſe of the Sun with their Eyes, from the riſing to the ſetting of it. I myſelf did in a clear Night in the Winter-time, collect the Light of the Moon by a Speculum, conſiſting of a Segment of a Sphere; and by ſuddenly looking at the Focus which was received upon white Paper, in order to determine by *Farenheit*'s Thermometer, whether there was any Heat perceptible in the Focus of the lunar Rays; I had by that means the Appearance of a white and ſplendid Circle before my Eyes in the Air, which continued for ſeveral Hours, inſomuch that I began to be afraid of Blindneſs. Aſtronomers uſually imitate Nature in this reſpect, by looking at the moſt ſplendid Objects through a ſmall Aperture to temperate the Rays of Light. *Rohault*, among the *French*, looking eagerly thro' a Teleſcope for a conſiderable time to obſerve a Battle at a great Diſtance, had the Uſe of that Eye vitiated for ever after. So great may be the Injury of ſuddenly admitting the luminous Rays to fall into the Eye, before the Pupil is warned and contracted. 2. A ſecond Uſe of this Apparatus is for it to dilate ſurpriſingly in a dark Place, and admit the Rays in the greateſt Abundance. For the Diameter of the Pupil being three times augmented, the Space admitting the Rays will be nine times larger; ſo that a Light nine times

times weaker, will affect the Eye equally as much as a full Light admitted through a contracted Pupil. Hence all our Pupils are dilated in the Evening, as any one may eaſily perceive, by adviſing his Friend to look at and diſtinguiſh the Colours of any Object in a dark Corner. 3. If the ſame Object be looked at in the Light, the Pupil will be contracted very ſmall. But we obſerve that it dilates, when we look attentively at any remote Object; as, for Example, at a Clock upon a Steeple in order to determine the Hour; for the Rays entering the Eye from the Object, are in a duplicate Ratio to the Diſtance; ſo that at twice the Diſtance, four times a leſs Number arrive at the Eye, at three times the Diſtance, nine times fewer are the Rays, and at ten times the Diſtance they are a hundred times fewer. Since therefore the Briſkneſs or Vivacity of the Sight depends upon the Number of luminous Rays which enter the Eye, and ſince from a remote Object there are but very few Rays received, therefore that Defect is aſſiſted in us by a Dilatation of the Pupil, which being enlarged, admits more Rays in proportion, as fewer of them are ſent to the Eye from the radiant Surface; and thus the Obſcurity of remote Objects is in ſome meaſure but not totally removed. But in a near Object as in a ſtrong Light, too great a Quantity of Rays may incommode the Eye: the ſame thing therefore takes place with reſpect to the Eye, in a weak Light, as we obſerved with regard to remote Objects; and in a ſtrong Light, as we obſerved with reſpect to near Objects. In Cats the Pupil has a different Fabric. For theſe are capable of ſeeing both in the Night-time, and in the Sunſhine of the Day without Injury. In this Creature there is therefore a double Curtain, by the receſſion or approaching of which, the ob-

long Aperture of the Pupil is increaſed or diminiſhed; for they are provided with particular Muſcles performing thoſe Motions. When they look in the Sunſhine, they draw theſe Curtains of the Pupil ſo cloſe to each other, that the Aperture or Slit betwixt them is no wider than a Hair: whereas in the Night-time, the Pupil is ſo dilated on all Sides into a Circle, that almoſt the whole Cornea appears black. The ſame Fabric is obſerved in Dormice. There are other Animals again, who having the Pupil very large, and not capable of contracting in this Manner, they can therefore only ſee in the Night-time, as the ſeveral Sorts of Owls and Night-birds.

§. 537. Therefore the more *plain* [1] or flat is the Figure of the Cornea, the leſs does it refract or converge together the Rays coming to it from any lucid Point, and the more does it ſpread them afterwards; ſo that fewer Rays are conveyed through ſuch a Cornea to the cryſtalline Lens, and thoſe alſo greatly diverging, unleſs they proceeded from ſome very diſtant Object: but the *rounder* [2] the Cornea, ſo much more does it unite or converge the Rays coming to it from any Point, and the more of them does it collect and throw upon the cryſtalline Lens, converging them very much together. And from hence we may underſtand the Reaſon of Short-ſightedneſs, called Myopes or Pur-blind, and of Dim-ſightedneſs in old People.

[1] Thoſe who have the Cornea thus vitiated, ſee near Objects more confuſedly, but remote Objects they

they ſee more diſtinctly; which is a Diſorder naturally following in old People, in whom the contracting Force of the Fibres overpowers the expanſive Impulſe of the Humours. In Infants the Eye is extremely ſpherical by a kind Providence of Nature, leſt they ſhould be too ſoon injured by the Rigidity or Inactivity of the Solids; but by degrees they become flatter, inſomuch that after fifty Years they are uſually incapable of ſeeing near Objects. But the Reaſon why flat Eyes ſee near Objects confuſedly, is, becauſe the Office of the Cornea being to refract or converge the Rays, more powerfully as it is more convex or perfectly ſpherical, it terminates them into a Focus too ſoon, as they converge more than they ought; for ſuch is the Proportion in the Fabric of a healthy Eye, as to determine the Focus itſelf upon the Bottom of the Retina. But when the Cornea is flatter than it ought to be, the Rays do not ſufficiently converge, but their Focus falls behind the Retina, as in the other Caſe it terminated before the Retina; ſo that in both theſe Caſes the Retina does not receive the Impreſſion of a ſingle Pencil of Rays, but of a great many ſeparated Rays. But when the Object is very remote, ſo that its Rays may be taken as parallel, flat Eyes are then capable of ſeeing the ſame more diſtinctly. Old People and thoſe who cannot ſee near Objects diſtinct from ſuch a Defect in the Shape of the Eye, are aſſiſted by convex Glaſſes, the Force of which refract or collect the Rays more together, ſo as to produce the ſame Effect as if the Cornea itſelf was more ſpherical.

[a] Of this kind are the Eyes of Children, who are frequently ſhort-ſighted from the too great Convexity or Roundneſs of their Eyes; but then ſuch have uſually their Sight better in old Age, ſo

that they need not the Aſſiſtance of Glaſſes. In this Caſe the Rays converge too much, and form a Focus before the Retina, too near to the Cornea; but the Rays naturally diverging again from that Focus, do not paint themſelves upon one, but upon many Points of the Retina. Such Eyes therefore will not be capable of ſeeing diſtant Objects: but the greatly diverging Rays of nearer Objects will not be ſo eaſily collected into a Focus before the Retina, by the greater refracting Power of the convex Cornea.

§. 538. The cryſtalline Lens collects ſtill nearer together the received Rays which were determined to it by the Pupil, and renders them converging in ſuch a manner, that thoſe which ariſe from one Point of the Object out of the Eye, are here again collected in a Point not far from the Body of the ſame Lens, paſſing through the vitreous Humour to the Retina, where they paint preciſely that Point only from whence they aroſe in the Object. If the cryſtalline Humour is very *denſe*[1] or round, then the Focus or Point of the collected Rays will be too near the Lens, whence the Sight will be confuſed; but if it is too lax or flat, the Point will be removed too far, whence alſo will ariſe confuſed Viſion: and hence again we have another Reaſon why People are ſhort and dim-ſighted.

[1] The Powers of Attraction are as the Denſities of attracting Bodies; and therefore a more denſe or compact Lens will attract the Rays more powerfully, and cauſe them to converge ſooner. From this

this Principle it may ſometimes happen that even old Men may be ſhort-ſighted. But when the cryſtalline Lens is more lax than uſual, it does not ſufficiently collect the Rays together; and under ſuch a State of the Lens, even young People may be troubled with the Dimneſs of Sight that attends old Age. But theſe Diſorders are not remediable by the Aſſiſtance of Dioptrics, nor are they ſcarce to be cured by any other Means.

§. 539. From hence therefore it is evident, why the Myopes or ſhort-ſighted are aſſiſted by a concave dioptric Lens, or by placing the Object nearer? and why the Preſbytæ or old People ſee more diſtinctly with a *convex* [1] dioptric Glaſs, or by removing the Object to a greater Diſtance? Both theſe may be accounted for from what has been ſaid before at §. 537, 538.

But theſe Defects (§. 539.) may be alſo remedied naturally, by bringing the cryſtalline Lens nearer to the Cornea, or removing it a greater Diſtance from thence; which Motions ſeem practicable two different Ways, namely, by compreſſing the *Globe* [2] of the Eye by a ſtrong Contraction of the four Muſcles at one and the ſame time, ſo as to render it more elongated; or, ſecondly, by a *Contraction* [3] of the Fibres or ciliary Ligaments (§. 522.) ſo as to compreſs the *vitreous* [4] Body, and thruſt out the cryſtalline Lens. Nor does there appear to be any other Cauſe in the Eye capable of producing this Effect.

[1] The Perfection of the Eye conſiſts in collecting the infinite Number of Rays which ariſe from any one viſible Point, ſo as to make them unite into one Point again upon the Retina, and paint there the Image no larger than a Point, nor yet divided into more Points than one. That this may be performed in the moſt exquiſite and perfect manner, it is neceſſary for the aqueous Humour and cryſtalline Lens to have a juſt or exact Degree of Denſity, while the Length of the Eye and Figure of the Cornea are at the ſame time adequate. If now the Eye becomes flatter than it ought, the Rays which come to it greatly diverging from a near Object, will not concur ſufficiently together to terminate in a Focus upon the Retina, where the Viſion will be therefore confuſed. From hence every body was, by this Depravity of their Sight, denied the Uſe of Books after the fiftieth Year of their Age, until by the modern Aſſiſtance of Glaſſes they were render'd capable of reading Books, the principal Delight that remains to wiſe old Men, without having their Letters an Inch long and broad. But now ſince the Invention of Spectacles, old People may read commodiouſly, by cauſing the Rays which come from ſeveral near Objects to converge more together, by which means they ſee them as diſtinctly as if they were placed at a great Diſtance. But, on the contrary, the Myopes or Short-ſighted render the Cornea as it were flatter by the Uſe of a concave Glaſs, which cauſes the Rays to enter the Eye in fewer Numbers, and more diverging, as if they came from a very near Object, making them unite together in a Focus at a greater Diſtance.

[2] Any Perſon who would ſee very minute Letters diſtinctly, ought either to remove them to or from the Point in which they can be beſt read.

But

But this Point is various in every Perſon. But to enable any one to ſee diſtinctly beyond this Point of Viſion, he muſt make uſe of other Helps. For the Figure of the Eye may be changed, when we are not capable of altering the Diſtance of the Object; and thus may the Sight be accommodated to view very diſtant or near Objects. This has been elegantly demonſtrated by Dr. *Pemberton* in his inaugural Theſis, where he maintains that a Sail cannot be diſtinguiſhed at the Diſtance of two Miles upon the Sea by the oldeſt Perſon, unleſs the Eye is ſo compreſſed by the four right Muſcles, as to render its anterior Part more convex: in the ſame manner as if a flexible Veſſel full of Water was to be preſſed more violently in three Parts than in the fourth, and then by adding a Preſſure from any Cauſe, the Part leſs reſiſting would then be preſſed out. Hence the Eye is tir'd or painful, when we accurately view a very diſtant Object; and if there is a Friend preſent, who endeavours to view well the ſame diſtant Object, you will perceive the Forepart of the Eye itſelf riſe up into a greater Convexity. We are not indeed ignorant of what *Perrault* has ſaid in Oppoſition to this Opinion, namely, that the Sclerotica of a Whale is almoſt an Inch thick; but then it becomes gradually thinner towards its anterior Part, where the Cornea is more than ten times thinner than the Sclerotica, ſo that it muſt neceſſarily give way to any Preſſure acting upon the Bulb of the Eye and its contained Humours.

3 This Contraction of the ciliary Ligaments is the ſecond Cauſe of diſtinct Viſion of Objects at different Diſtances. For the ciliary Ducts or Ligaments are incumbent both on the cryſtalline Lens and vitreous Body; ſo that when this Tunic is contracted (§. 520, 522.) it changes the Tunic of the

the vitreous Body from a right Line into an Arch; and then the cryſtalline Lens is without doubt thruſt forward, becauſe a Preſſure is exerted upon the Sides of the vitreous Body, while its Middle remains free. Theſe two Cauſes render the Eye a moveable Teleſcope, capable of accommodating it ſelf to Objects at all Diſtances, and of changing their focal Points. A moſt profound Geometrician has wrote upon this Subject, and looked upon the ciliary Tunic to be a ſpiral Muſcle to the cryſtalline Lens, which he thinks it is capable of flattening, or rendering more convex; and it is likewiſe thought that the Lamellæ of the Cryſtalline may by the ſame Means be preſſed cloſer together, or removed at a greater Diſtance aſunder. But this Author has aſſumed ſeveral things which ought not to be allowed by every body. For my own part, I make uſe of no other Aſſiſtances than what are to be found in the Eye; and I believe this Explanation to be every way ſufficient to account for the Appearances.

[4] Then the cryſtalline Lens is thruſt forward, while the vitreous Body becomes more compact, ſo as to more accurately collect or converge the Rays, and to determine their Focus into a very ſmall Point. And in this Manner is the Eye changed, when we accurately examine very minute Objects; nor is any great Alteration required in order to direct the true Picture of the Object upon the Retina.

§. 540. The *Refraction* [1] of Rays paſſing out of the Air through the Cornea, is equal to that of Rays falling out of Air into Water; and the Refraction of them from the aqueous Humour into the cryſtalline Lens, is nearly the

the ſame with that of a Ray, paſſing out of Water into Glaſs, which is but ſmall; and laſtly, the Refraction which happens from the paſſing of a Ray out of the cryſtalline Lens into the vitreous Body, makes but little Alteration; or the vitreous Body being compreſſed and rendered more denſe, may perhaps make the Difference little or nothing; and therefore the Neceſſity of the vitreous Humour ſeems principally to be, for retaining the cryſtalline Lens freely moveable, ſo as to be capable of accommodating itſelf to the Retina at different Diſtances; while in the mean time the Maſs of the cryſtalline Lens itſelf, retains its Figure more firmly or conſtantly than the vitreous Body.

[1] This Refraction is conſtant in the aqueous Humour, ſince like Water it is incompreſſible, and therefore its Denſity remaining the ſame, its Refraction will not be altered. Water indeed is a little rarified by boiling, and refracts leſs; but when congealed into Ice, it refracts a little more: but theſe Alterations do not take place in the Eye of the living Animal. But in the cryſtalline Lens the Refraction is altered, as well as in the vitreous Body, which conſiſting of Sacculi may be compreſſed, ſo as to increaſe a little their refracting Power. But it was neceſſary for the vitreous Body to be ſofter than the Lens, that it might be capable of changing its Place.

§. 541. The whole Apparatus then occaſions a diſtinct and vivid Collection of thoſe Rays which come from any one *Point* [1] of an Object,

Object, ſo as to make them meet in the Bottom of the Eye directly under the Pupil; and thus penetrating the Cornea, Pupil, and cryſtalline Lens, they *paint* [2] as many diſtinct Points upon this Bottom of the Eye, as are conſpicuous in the Object, a ſmall *Image* [3] of which is therefore painted upon the *Retina* [4].

[1] The Eye cannot ſee more than one Object diſtinctly at a time. This may indeed ſeem a Paradox to ſome, but it is matter of fact, as any one may demonſtrate to himſelf. For Inſtance, take up a Book, and you may ſee a whole Page at once, but endeavour to read it, and you will not find it poſſible to read all the Lines of the Page at once, but ſome will appear diſtinctly and others confuſed: nor yet can you read one Line at once, for in the ſame Series of Letters, ſome will appear languid and others more vivid. The Mind then ſees but one Letter at a time, ſo as to diſtinguiſh and read it accurately; and though it ſees the reſt, it is in a confuſed Manner. If you ſee a Grain of Sand removed to the Diſtance of one Foot, you will there perceive it very diſtinctly by looking at that alone; and yet I affirm that you cannot ſee the whole Grain of Sand diſtinctly, for every one of its Parts may be afterwards viewed diſtinctly or apart, when the Eye ſucceſſively fixes itſelf upon ſingle Points of the ſame Grain. But then, why does it ſeem to ourſelves as if we ſaw many things at once? This is, becauſe the Eye with incredible Velocity is adapted to run over many Objects in the ſmalleſt Inſtant of Time. Nor does the Senſe or Impreſſion of Objects immediately vaniſh, ſo that the firſt Letter is not loſt in order to attend better to the next, but the Image of the former is retained

retained in the Mind for ſome time, together with the new Image of the laſt, and applied together in ſo ſmall an Inſtant, that they ſeem to ariſe in the Mind at once. If a Stick three Feet long, with one End of it burning, be whirled round in a Circle, at the Diſtance of ſix Feet from the Eye, it will afford the Appearance of a fiery Circle, when at the ſame time the Extremity of the Stick is only viſible as a ſingle Point; namely, becauſe the firſt Image continues in the Eye, till it is followed by the ſecond and third, *&c.* Boys make a red Spot upon the Head of a Whipping-top, and by working it round very ſwiftly by the Scourge, that Spot ſeems to be a red Ring, becauſe the ſtronger Colour continues in the Eye, renewing the ſame Senſation in different Points of the ſame Circle, with incredible Swiftneſs: thus true is it, that we do not ſee ſeveral things diſtinctly at one time, but the Mind is deceived by the laſting Impreſſion of the Image, and great Velocity of the ſwiftly moving Eye, by which things ſeem to appear preſent at one Inſtant, which follow ſucceſſively after each other.

[2] In an Eye, which has been taken out of the Orbit, and cleared of all the Fat, let the back Part of the Sclerotica be cut off oppoſite to the Cornea, and inſtead of the Sclerotica apply a Piece of white Paper; by that means if you look on one Side, the Images of the circumjacent Bodies will appear painted upon the Paper, which is placed inſtead of the Retina behind the vitreous Body.

[3] So long as the Rays converge together, from an infinite Number of Points in the Object, into one within the Eye, the Image will be painted like the Object; but when they fall ſeparately, the Object will be either multiplied or the Sight confuſed. I ſaw a Man who beheld every Object

as

as three, in whoſe Cornea perhaps there might be ſeveral Planes like a multiplying Glaſs. But it is poſſible for the Rays proceeding from an infinite Number of Points, to converge together into one upon the Retina, as may be demonſtrated from that Propoſition of *Euclid*; namely, that the ſame Number of right Lines may be drawn in the leaſt Circle, as in the largeſt, and the ſame Number of Diviſions made in one as in the other.

[4] The cryſtalline Lens ſpreads the Rays very largely round the whole Surface of the Retina. The Magnitude of the Cornea being given, with the Depth of the Eye, and Convexity of the cryſtalline Lens, let a right Line be drawn through the Middle of the Cornea and Pupil to the Sides of the cryſtalline Lens; and thus you will ſee what Part of the Eye is illuminated by the Lens, after the Rays have been refracted. It is almoſt a third Part of the Eye, the other two Thirds of that Organ being blind or inſenſible.

§. 542. Now as the mucous or ſoft Pulp, namely, the Medulla of the optic Nerve, is ſeated *directly* [1] in this Point, under the Pupil and cryſtalline Lens; this is evidently the Part which receives the Pictures of the Objects, and conveys by its Continuity the Impreſſion of the Image to the common Senſory, ſo as to excite in the Mind an Idea of the thing ſeen.

[1] The optical or viſual Axis of the Eye, determines the Point of Viſion to fall upon the expanded Medulla of the optic Nerve, and therefore the Image of the viſible Object falls upon the Medulla itſelf of the Brain. There, that is in the Medulla of

of the Brain itſelf, the Mind ſees, and not the Eye, as *Ariſtotle* juſtly obſerves. But it is not the Buſineſs of a Phyſician to enquire what Viſion is in the Mind, only he is to know what it is in the Eye; for let the Eye be ſound or duly formed, and the Inhabitant will ſee by it, as *Paracelſus* rightly obſerves.

§. 543. Even this medullary Expanſion of the optic Nerve, appears evidently to be the Seat of Viſion from the Experiments of *Picard*[1] and *Mariot*; ſo far are thoſe Experiments from oppoſing the ſame thing, as ſome Authors have imagined. And here the infinite Wiſdom of the Architect is to be admired and adored, for not placing the Entrance of the optic Nerve in the Axis of Viſion, nor towards the external Angle of the Eye, but in a Middle Altitude, and towards the Noſe.

[1] A Perſon who can ſee moſt diſtinctly, may direct his Eye in a certain manner towards the Noſe, ſo as to ſee a black Spot upon it. And this happens when the Eye is ſo turned by the Action of the oblique Muſcles, that the Center of the optic Nerve looks towards the Noſe; for that Point in the Center of the Nerve is blind. Upon this is founded the celebrated Experiment of *Mariot*, and that of *Picard*. Namely, let a Perſon meaſure the Heighth of his Eyes upon a Wall, and there make two black Spots, at the Diſtance of a Span from each other, or at a Diſtance equal to that of the Eyes from each other; and then let the left Eye be ſhut, after which the right Eye will ſee both the Spots: when this is done, let the right Eye be directed towards the left Spot, and

and let him recede backward by degrees, and at a certain Diſtance the right Paper will become inviſible. This happens when the Spot is oppoſed ſo obliquely to the right Eye, that the Axis of Viſion falls at the Diſtance of a ſixth Part of the Diameter of the Eye, meaſuring from the Noſe; for then the Object is oppoſite to the Artery which lies in the Middle of the optic Nerve, ſo that the Eye is perfectly blind to that Object. The celebrated Geometricians *Picard* and *Mariot* obſerving this Experiment, from thence concluded that the optic Nerve was not the Organ of Viſion, and therefore ſubſtituted the Choroides for that Office inſtead of the Retina; for then, ſay they, we ſee nothing of the Object, when it falls directly upon the Middle of the optic Nerve. But in that Caſe the Image is not impreſſed upon the optic Nerve, but upon the Artery which runs through it; whereas the Nerve only is ſenſible, and not the Artery. From this Obſervation a Reaſon may be given, why the optic Nerve is rather inſerted towards the Noſe, than in the Middle or oppoſite to the Axis of the Eye, or even towards the external Angle; namely, becauſe the Eye would then be blind to all remote Objects; whereas now only that Point is blind which falls towards the Noſe, the Sight of which is leſs neceſſary, and falls upon a Part of the Object, which we never loſe Sight of, ſo long as we enjoy the Uſe of both Eyes. Thus have we explained that wonderful Fabric of the Eye, the Perfection of which admits of no Improvement, and upon which the whole Science of Dioptrics is founded.

§. 544. The *Perfection* [1] of Sight therefore depends upon ſuch a *Figure* [2], *Pellucidity* [3], *Fabric*

Fabric 4 and *Power* 5 of the Solids, together with ſuch a Denſity and Pellucidity of the colourleſs *Humours* 6, as may beſt determine or collect the greateſt *Number* 7 of Rays coming from a viſible Point of an Object, without mixing with others into one diſtinct Point of the Retina, placing the Focus neither too near, nor too *far from* 8 that nervous Expanſion: and further, the Perfection of Sight conſiſts in ſuch a free *Mobility* 9 of the ſolid and fluid Parts of the Eye, as will be ſufficient for the clear and diſtinct painting of Objects, though placed at different Diſtances; for thus the Ideas of Magnitude, Figure, Diſtance, Situation, Motion, Reſt, Light and Colours are beſt repreſented: and laſtly, it is neceſſary for the Retina to have that Situation, Expanſion, *Senſibility* 10 and Tenderneſs, together with a due Proportion betwixt the medullary Subſtance, and *arterial* 11, venal and *lymphatic* 12 Veſſels, as will ſuffice to tranſmit the Images freely and unaltered through the well-conditioned optic Nerve, to the common Senſory.

1 The Knowledge of this Perfection of the Eye, leads us to find out Means for aſſiſting the ſeveral Diſorders of the Sight. But the Perfection of the Eye is greateſt from the eighteenth to the fiftieth Year of Age, and conſiſts in our ſeeing many Objects very ſtrongly and diſtinctly, without any Increaſe or Decreaſe at different Diſtances, ſo as to behold the moſt remote and near Objects fully and accurately (ſee §. 522.) From this Definition of the Perfection of Sight, there ariſe three

Claſſes of Diſeaſes. In the firſt of which, the Eye is adapted to ſee only at one Diſtance, or can obſerve well only very remote, or elſe very near Objects. 2. If the Eye does not ſee briſkly, it is called a Dulneſs or Imperfection, the Object then ſeeming as if it was obſerved through a Cloud in the Middle of the Day; and this Diſorder is frequent to old People, whoſe Eyes begin to be opake. 3. Laſtly, The Viſion may be undiſtinct. The Diſtinctneſs of Viſion ariſes from an infinite Number of Rays converging together into one Point, which falls exactly upon that Part, in which the optic Nerve covers the Eye. When the Focus or Point of converging Rays falls behind the Retina, the Rays then come to it ſeparated, or before they are collected together, and therefore paint not one but many Points upon it. When the Rays converge more than they ought, the Focus falls betwixt the Retina and the cryſtalline Lens; and then from that Focus which they make in the vitreous Body, they diverge again and paint many Points, when they ought to paint but one. From both the preceding Defects ariſe a Confuſion of the Images in the Eye, whether they are ſeveral or ſingle. Theſe contrary Defects of the Sight are eaſily demonſtrated from the Particulars required in the moſt perfect Sight.

[2] The Convexity of the Eye determines the Rays in a Focus upon the Retina, ſo that they do not converge before or behind the ſame. The Eye ought alſo to be perfectly ſpherical, ſo as to be ſuſceptible of the greateſt Number of Rays.

[3] The Pellucidity of the Eye ought to be as perfect as poſſible; for ſo ſoon as there is the leaſt Opacity, the Eye is continually deceived, though it ſhould be free from all other Defects. Thus the Pupil ought to be very black; and in general the

the Eye is better, as the Pupil appears blacker. Nothing ought to be ſeen in the Pupil unleſs the reflected Image, as if coming from a Glaſs; for if there is the Appearance of the leaſt Whiteneſs perceptible in the Pupil, the Sight is always dull in proportion.

[4] The leaſt Alteration in the Fabric of the ſolid Parts excites Diſeaſes of the Eye. I examined the Cornea in the Eye of an Ox, by preſſing upon the Back-part, to diſtend the Cornea outward as much as poſſible, in the ſame manner as it is obſerved in the living Animal; and then with a very ſmall Needle and a Microſcope, I punctured the exterior Surface of the Cornea ſlightly, by which means an elaſtic Lamella or Pellicle of the Cornea contracted and enlarged the Opening; and then again I repeated the ſame Puncture through the next entire Pellicle, which contracted and made a new Opening as before: and in this manner a hundred Strata may be diſtinguiſhed in the Cornea, by puncturing as many times; whence the Cornea appears to be made up of an infinite Number of concentric Strata. But it is remarkable, that at each Puncture a ſmall Quantity of Water was diſcharged; and therefore the Cornea ſeems to be alſo compoſed of very fine lymphatic Veſſels, many of which are interwove into a Stratum, ſeveral of which Strata make up the whole Membrane of the Cornea. Now if any one of theſe Strata is vitiated or diſeaſed, the Perfection of the Sight will be impaired; but if a ſmall Fiſſure or Wound be made in the Surface of the Cornea, the divided Lips receding, would conſtitute two different Planes or Surfaces, which would continually occaſion a Duplicity of Sight.

[5] Namely, their Power of Elaſticity, which is in proportion to the Extenſion that they ſuffer

from the Humours. Whenever the Equilibrium is altered betwixt the Solids and Fluids of the Eye, that Organ is always more or leſs vitiated or diſeaſed. When the Power of the Solids prevails, the Eye becomes flatter, as in old People; but when the Humours too much extend the weakened Solids, the Eye becomes ſhort-ſighted, or even at length may be ſo protuberant and extended, as to acquire the Denomination of *Oculus elephantinus.*

[6] Theſe Humours are, 1. The pellucid Lymph contained in the ſmall Veſſels of the Cornea, continually moving in the Courſe of the Circulation. 2. The aqueous Humour. 3. The Humour which circulates through the parallel Veſſels of the cryſtalline Lens. 4. The Humour contained in the very ſmall Veſicles of the vitreous Body. In all theſe Humours is neceſſary a perfect Degree of Pellucidity with a certain Denſity. When they are leſs denſe, they cauſe the Focus of the Rays to fall at a greater Diſtance from the cryſtalline Lens, even behind the Retina; but when they are more denſe, the Focus then terminates too near the Lens, and even before the Retina. But it is to be obſerved, that theſe Humours are capable of being condenſed or rarefied, ſince they are not like mere Water, but in ſome degree compreſſible. Laſtly, When theſe Humours of our Eye are coloured, they then repreſent not the true Colour of the viſible Object, but that of the Humour itſelf to the Mind: thus when the Eyes are yellow, as in a Jaundice, all the Objects ſeem to be yellow.

[7] The more numerous the Rays which are collected together into a Point, the more vivid is the Sight or Impreſſion of the Object; and the ſmaller the Point in which they converge together, ſo much more diſtinct is the Sight. If the Focus of

Rays

Rays fell one thouſandth Part of an Inch before the Retina, the Image would not be painted in a ſingle Point of the Retina, but in many, and the Viſion would be confuſed.

[8] The Image of a remote Object appears diſtinct, when the Rays come to the Eye in ſo ſmall an Angle, that they may be taken for parallel. But in that Caſe the vivid Strength of Viſion is wanting, becauſe the Rays are ſent into the Eye in a ſmall Number. Thus an old Man will be capable of ſeeing diſtinctly at the Diſtance of a whole Mile, but then he will not ſee with any great Strength; on the other hand, when the Eye can only ſee near Objects, the Sight is then leſs perfect (ſee §. 530.); for it is better to ſee remote Objects well, than to be obliged to view them at the Diſtance of an Inch, in order to ſee them diſtinctly.

[9] So moveable, that in an Inſtant of Time the vitreous Body ought to be capable of changing its Solidity, and the cryſtalline Lens its Situation. But when the Eye itſelf is perfectly moveable, it then receives an infinitely greater Force of the Rays, while it moves through one fourth Part of a Circle; ſince this Arch is in the Center of an infinite Number of larger Arches, from whence all the Rays are received.

[10] Namely, Senſibility or Sharpneſs of perceiving. The Retina cannot be affected by Objects, but in proportion to its own natural Senſibility. When I look at the full Moon in a clear Night, my Eye may be ſo affected that I can retain the Image as if it were preſent, by turning round with my Back towards it; but when the Image of the full Moon is collected by a concave Speculum, and thrown upon white Paper in a ſingle Point, in that caſe the Impreſſion of a lumi-

nous Spot will remain for ſeveral Hours as if it were painted in the Eye; and by this means a Man may be quite blinded, though there is not any Heat produced in the Focus, capable of being diſtinguiſhed by the moſt ſenſible Thermometer, even that invented by *Drebel*, which ariſes even by a Blaſt of one's Breath. Hence we infer, that the Retina of a healthy Perſon ought to be ſo ſenſible, and capable of Irritation, as to be affected by the leaſt Cauſe or corporeal Action. Upon this natural Senſibility of the Retina, the Sharpneſs of Viſion in a great meaſure depends; and this Senſibility being loſt in old Age, the Eye itſelf is no more affected by the Sun than the Skin, namely, it continues only ſenſible of Heat.

" We ſaid before that the optic Nerve in its Center is not nervous, being perforated with an empty Aperture, through which a conſiderable ſanguiferous Artery paſſes in the middle of the Cylinder of the Nerve, expanding itſelf together with the Retina; upon which Artery the Image of the Object falling, is not perceived by the Mind under any other Form than that of a black Point. Now when theſe Blood-veſſels in the Bottom of the Eye are ſo diſtended as to compreſs the Medulla of the optic Nerve there alſo expanded, the Retina itſelf will be likewiſe inſenſible. This Opacity or Inſenſibility in any Part of the Retina, is not aſcribed to the Eye by the Mind; but when the Perſon looks in a ſerene Air, he ſees at a Diſtance as it were dark Particles dancing in the Air, which are nothing more than inſenſible Points of the Retina, whether that Inſenſibility ariſes from a Palſy, or from ſome Body placed in the Bottom of the Eye before the Retina.

" *Ridley* opened the Eye of an Animal lately ſtrangled, by dividing its anterior Membranes, and

and he obſerved that in the Retina and optic Nerve there were diſtributed lymphatic Veſſels, which did not intercept the Rays of Light, ſince they were extremely pellucid. But if the ſame Veſſels from any Cauſe ſhould be rendered leſs pellucid, then the Sight would be loſt in thoſe Points of the Retina, and the Mind will perceive as it were Bubbles of Water, like what People frequently ſee in the Clouds, when illuminated by the Noon-ſun; namely, the Appearance of pellucid and dancing Globules. There is no Danger from the Appearance of theſe Corpuſcles, as I have experienced in myſelf.

§. 545. The viſual Rays do *not* [1] therefore *flow out* [2] of our Eyes, ſo as to be reflected again into them from Objects, as the Stoics have aſſerted. Nor do we ſee by any viſible Species flowing out of the Object into us, as *Pythagoras* and his Followers have pronounced; nor yet do we ſee Objects by Effluvia which they emit to the Eye, becoming viſible by embracing each other, and then returning again, according to the ſtrange Reaſonings of the *Platoniſts*; nor, laſtly, do we ſee by any material Efflux of corporeal Images, as *Epicurus* [3] judged. But Viſion is performed by that *Mechaniſm* [4] which has been explained before, and the underſtanding of which has been much expedited by an accurate Deſcription of the internal Organ of the Eye, by the celebrated *Raw* communicated in an Epiſtle to me.

[1] Viſion is the Perception of a moſt ſubtle Body, and belongs in a manner as well to Spirits as to

Bodies. Specula reflect the Images of Bodies ſo accurately, that there is no living Creature who has not been uſed to them, but what would believe he actually ſaw the Perſon or thing itſelf, whoſe Image only is painted in the Speculum. Thus we ſee Dogs placed before a Looking-glaſs, move their Head and Eyes variouſly, in order to diſcern whether that which they ſee is a real Dog. This we know not what thing, which ſo much reſembles the Body from whence it is derived, has hardly any Extenſion, and yet it ſeems equally extended with the Body itſelf.

[2] If we ſaw by Rays flowing out of the Eyes, we ſhould not then ſtand in need of Light; but certain we are that without Light we cannot ſee. I am not indeed ignorant that there are ſome Inſtances which are alledged in favour of the contrary Opinion: as *Tiberius*, who riſing up ſuddenly in the middle of the Night, is ſaid to have been capable of diſtinguiſhing all Objects; and in ſhort, I believe that this Accident is not unfrequent, but that many Men may for a Moment clearly perceive with their Eyes when they open them in the middle of the Night. But neither does this conſtantly happen to the ſame Perſon, nor is it of any Duration, the ſhort Light being inſtantly followed in the ſmalleſt Moment of Time with a profound Darkneſs; nor does this proceed from Rays ſent out from the Eye. In ſhort, the whole Affair is as follows: The Eye may become ſo tender, that what is no Light to others, may yet be ſufficient to illuminate a tender Eye; for, properly ſpeaking, there is no ſuch thing as Darkneſs throughout the whole World; but we call that Darkneſs, which is a weaker Light; inſomuch that Places ſaid to be dark to us, are yet by other Animals taken for clear Lights, and, on the other hand, our

our Light is again taken for Darkneſs by thoſe Animals. Thus a Man is capable of ſeeing in the Day-time, but at that time he cannot be ſeen by a Dormouſe; on the other hand, we are blind in the Night, at which time the Dormouſe ſees, ſearches for its Prey, and obſerves every thing very accurately. Thus alſo a great many Flies, eſpecially thoſe which have many Eyes, with half the Sorts of Butterflies and other Animals, do not ſee many things well but in the Night. A memorable Inſtance of this Nature happened in *England*, which was cited before (§. 490.), Of a Man who being thrown into Goal and deprived abſolutely of all Light, both from the Sun, Moon, and Heavens, he could not ſee any thing for a conſiderable time; but after a while he began to perceive a faint Twilight, after the Pupil had relaxed itſelf, and in proceſs of time, his Eye became ſo tender, that he could both ſee Objects and read Letters in the moſt profound Darkneſs. Nor is there any thing very ſurpriſing in all this; for there is hardly a Phyſician who has not obſerved, that upon coming out of a ſtrong Light of the Sun in the Summer-time, to a Patient lying ill of an acute Diſeaſe in a dark Chamber, he has not been capable of ſeeing for the Space of half a quarter of an Hour, during which Time becoming more accuſtomed to the Darkneſs, he has diſtinguiſhed the Objects as if it were by a Light gradually more and more increaſing. Namely, the ſtrong Light had ſo affected the Eye, as to render it inſenſible of a weaker Light; when the ſame Eye will be able to ſee in the weakeſt Light after it has been deſtitute of one ſtronger. But to return to the Matter concerning which we were ſpeaking; it is by no means reaſonable to ſuppoſe Rays flowing out of our Eyes, which meeting with Objects are reflected back

again

again to the ſame, ſo as to bring with them the true Images, and as it were the Shells of the Bodies to the Bottom of the Eye; or elſe that Rays coming out of the Eyes, unite with Rays coming from the Objects, and ſo return together to the Eye; for all theſe Opinions are eaſily refuted, ſince a good Eye cannot perceive any Object without the Aſſiſtance of Light.

[3] This falſe Opinion is not juſtly aſcribed to *Democrates*; namely, that viſible Images or Pictures wander about every way from Bodies, and are received by the oppoſite Eye. For this Notion is refuted by the former Argument, that upon removing Light, Viſion is deſtroyed. Theſe Images are the Spectra deſcribed by *Virgil:*

Et ni docta comes, tenues ſine corpore vitas,
Admoneat, volitare cava ſub imagine formæ,
Irruat & fruſtra ferro diverberet umbras.

[4] Which Mechaniſm is as conciſe as poſſible, namely, a Collection of the Rays reflected and diſperſed from the radiant or reflecting Point to the Eye.——What has been hitherto ſaid concerning the Eye, may be ſafely adhered to, and ſupported by ſolid Experiments. But as *Ariſtotle* formerly pronounced very juſtly, it is the Mind which ſees and the Mind which hears; whereas the Object itſelf is only a characteriſtic Mark, which excites an Impreſſion in the ſenſitive Faculty of the Mind. It may be added, that Viſion does not belong to Bodies, but depends on the Faculty of the Mind itſelf, which is capable of repreſenting to itſelf Images, without the Aſſiſtance of Bodies, both when we are ſleeping and waking. Even Sir *Iſaac Newton* ingenuouſly confeſſes, that all which has been taught by optical Demonſtration, produce

no

no more than a certain Change in the optic Nerve; and therefore we do not ſee Images by their Impreſſions on the optic Nerve any otherwiſe, than as if a Preſs or other Body was repreſented by Lines drawn with Ink upon Paper; the Lines themſelves having no Relation to the Preſs or Body which they repreſent. For the Focus of Rays meeting together upon the Retina, produces nothing but a true kind of Touch or Feeling; and yet from that Focus ariſes the Idea of red or other Colours. It therefore does not follow, that the Eye is affected or tinged with a red Colour, when that Idea is excited in the Mind; but the Mind has a Faculty of framing particular Thoughts or Ideas, when it is moved in a certain Manner or by certain Bodies; nor will that Colour ever ariſe, unleſs the corporeal Organ is moved in the ſame manner, by the Body or Object, by Diſorder or by the Mind itſelf. And this may be taken as a certain and infallible Law; for the ſame Object will conſtantly excite the ſame red Colour in the healthy Eye of every Perſon throughout the whole World. But our Ignorance of the Manner in which theſe Ideas are excited in the Mind, ought not to give us any Uneaſineſs; for the Buſineſs of the Phyſician extends no farther than to keep the Eye ſound and duly diſpoſed, that the Rays may meet together in a juſt Manner upon the Retina.

§. 546. From what has been ſaid, we may be able to give a Reaſon why Objects appear moſt clearly when placed at the *leaſt* [1] Diſtance that the Eye will bear, ſo as to ſee them *diſtinct* [2]? and why when the Object is removed at a greater Diſtance, it is ſeen diſtinctly but

but not ſo ſtrongly or evidently, producing a more languid Effect upon the Eye? why Objects appear *confuſed*? when placed too near the Eye? what is required towards a diſtinct, and what towards a ſtrong or vivid Sight of Objects, *&c.*? All which may be eaſily ſolved from what has been before advanced.

' In every Perſon there is a determinate Diſtance, at which Bodies are beheld by them moſt diſtinct, or as plain as they are capable of appearing. A Perſon whoſe Eyes are diſtinct will plainly ſee and know another Perſon at the Diſtance of two Feet, and alſo at the Diſtance of twenty Feet; but what is ſeen at a greater Diſtance appears weaker, and that which is ſeen at a nearer Diſtance appears confuſed. For Inſtance, I ſee a white Sail at the Diſtance of a Mile diſtinct enough, but not vivid or ſtrongly; but as the Ship approaches nearer, I perceive the Sail more apparently or clearly as it comes nearer. But when that Sail comes within the Diſtance of twelve Inches I then ſee the Threads, which being wove together make up the Sail, and alſo the ſmall Filaments or Fibres of the Flax which are twiſted together into the Threads. In effect, we ſee beſt or moſt clearly, when the Object is placed at ſuch a Diſtance, as may enable it to ſend the greateſt Number poſſible of parallel Rays to the Eye, ſo as to make them converge upon the Retina; and therefore Viſion is moſt vivid when the Eye receives the greateſt Number of Rays, and the moſt diſtinct when they come parallel, and terminate as before upon the Retina, ſuppoſing the Eye itſelf to be as perfect as poſſible.

We

[2] We then ſee diſtinctly becauſe the Rays are almoſt parallel, only they are but few in Number; by the former the Viſion is rendered diſtinct, but by the latter more faint. But the Number of Rays from an Object diminiſh in proportion to the ſquare of their Diſtance.

[3] When a Needle is applied as near as poſſible to the Cornea, it cannot be ſeen, becauſe the Rays reflected from the Needle, diverge ſo much that they terminate in a Focus behind the Retina; and therefore we ſee many Points inſtead of one.

Of the HEARING.[1]

§. 547. SOUND[2] is a tremulous Motion of the common *Air*[3], ariſing from its *reciprocal Vibrations*[4] or *Tremors*[5] and Elaſticity, when ſtruck or agitated by a *ſonorous*[6] Body. It is propagated from the ſonorous *Center*[7] in *right Lines*[8], towards the Circumference of a Sphere, as far as it is capable of extending, being nearly ſubject to the ſame Laws in its Progreſs and *Reflexion*[9], which we obſerved in the Rays of Light; (§. 533.) only it is propagated more ſlowly and *ſucceſſively*[10], namely, paſſing over the Diſtance of 968 *Engliſh* Feet, within the Space of a Second of Time: a greater or *leſs*[11] Sound moving equally, and without being accelerated or retarded by moving with or againſt the *Wind*[12], though in the latter Caſe, the Sound

Sound does not extend to ſo great a Diſtance; in the mean time the Sound *impreſſes* [13] its Tremors againſt elaſtic Bodies which oppoſe it, and theſe elaſtic Bodies reflect the Tremors again with very little Alteration. Hearing then is the Perception of ſuch a Sound excited in the Mind, by means of that whole Organ which we call the Ear, as well internal as external.

[1] Hearing is that Idea or Perception of Sound, which is excited in the Mind by the ſeveral Parts or Organs belonging to the Ear; and thus true Hearing is diſtinguiſhable from the Idea of Sound, which ariſes in the Mind from an internal Cauſe.

[2] Sound is every thing capable of being heard, which exiſts without us, in a tremulous Motion of the Air agitated into Waves. But with regard to ourſelves, it is a Mode of thinking or perceiving Ideas in the Mind, which every one is ſenſible of, and no one can explain.

[3] That the Air is the Inſtrument or Medium of Sound is evident, ſince without it no Sound can be heard. That the Air is the Medium which conveys Sounds, may appear among other Experiments from the following; namely, becauſe the Sound of a Bell which I now hear being cloſe to it, will in a Second of Time be heard by another Perſon at the Diſtance of a thouſand Feet from the ſame Bell. But Water is not the true and adequate Medium of Sound, although Fiſhes are capable of hearing by it; for the tremulous Motion of the Air is continued from thence confuſedly through the Water, but that Communication will be cut off if all the Air is extracted and excluded.

Sound

4 Sound being once formed continually loſes itſelf, and is ſpread to other Parts where it may be heard; nor is it the ſame Sound that continues to be heard, but others which ariſe after the firſt. We are much deceived if we judge Sound to be one continued Motion of the Air. For Example, let there be a large pendulous Bell, namely, a hollow copper Body approaching the Shape of a Cone; and let it be ſtruck gently in the Rim, a Sound will ariſe which will continue for ſome time, and ſeem conſtant, provided no Alteration is made in the Bell. But if the Hand is applied at that Inſtant when the Sound ariſes, ſo as to ſtop the Tremors of the Metal, the Sound will then periſh as to ourſelves, ſo as to be no longer audible; but a Perſon who is 968 *Engliſh* Feet diſtant from the Bell, when it was firſt ſtruck, will hear the ſame Sound exactly after the Space of a Second of Time; and then after another 3600th Part of an Hour, the ſame Sound will be heard by a Perſon who is almoſt near 2000 Feet diſtant. Therefore the firſt Sound which you ſuppreſſed in its Origin by the Hand, was not durable or permanent for any time, but it is loſt the Moment after it is perceived by the Ear, and in the ſecond Minute of time another Sound ſucceeds the former and affects the Ear, and ſo a third in a continued Succeſſion. Sound therefore is continually deſtroyed but maintained and renewed by other Sounds from the trembling Bell; but if you ſuppreſs the Tremor of the Bell, then the whole Tone or Sound is at once deſtroyed. Therefore a ſingle Vibration of a Chord is not audible, but if the ſonorous trembling Body which is ſtruck, cauſes the Air to recede and return alternately to a certain Number of times in a given Space, then that Number of Impulſions or vibrating Motions of the Air, which are made in a given

given time by the ſonorous Body are called Sound. This Doctrine has been elegantly treated by Monſ. *Sauveur*, *Hiſt. del' Acad. ann.* 1700. *p.* 172. He made uſe of one of the largeſt Church-organs, in which the Tones are very diſtinct, and may be continued to any time with Pleaſure; which cannot ſo well be done by any other muſical Inſtrument. The largeſt Pipe of all in the Organ makes the whole Church tremble, when it yields the due Tone; but if the ſame Pipe was perfectly cylindrical, and of the ſame Diameter on all Sides, it would not yield any Tone. But if the Air which is blown in, is obliged to paſs through a narrow Aperture, then a Tone or Sound ariſes; whence it follows, that Sound is not a bare blowing thro' of the Air, but a Colliſion or beating back of the ſame in an undulatory Motion. If theſe Undulations of the Air are too ſlow, and not repeated in a ſufficient Number in a given time, it will not be perceived by our Ears, even though it may perhaps be audible to other Animals. If the Artiſt makes the Pipe too ſmall, it yields an intolerable Stridor or Squeaking; and betwixt this diſagreeable Stridor and too great a Tone, which is not audible, is the Limits of audible and true Tones; which ariſe from a juſt Number of Undulations in the Air in a given time, being neither too frequent nor too ſlow in their Succeſſion.

[5] A tremulous or reciprocal Vibration of the Air. But the Vibration is ſaid to be reciprocal, when it is impelled one Moment from A towards B, and the next Moment returns again from B towards A: for a continued or equable Motion of the Air however ſtrong, never produces Sound. The moſt ſwift and ſtrong Wind will yield no Sound of itſelf; and if you ſtand in a level Plain, you will not perceive any Sound, except what ariſes

ſes from the Colliſion of it againſt the Surface of the Earth, and againſt your own Cloaths. And in the moſt violent Storm of Wind upon the Sea, there is no other Sound to be heard, but that ariſing from the Conflict and Claſhing of the Waves. The greateſt Force of the Wind blowing upon a moſt high Tower, affords no other Sound than that which proceeds from the Colliſion of the Air againſt the Walls, which is indeed a Sound terrible enough, ariſing from the Stones, and not from the Air alone. Theſe reciprocal Motions of the Air, which we call Tremors, produce Sound, when five or ſix hundred of them ſucceed each other within the Space of a Second; whereas if fewer Tremors ſucceed each other in that Space of time, no Sound follows. If a muſical Chord which ſounds the loweſt Note of all the Baſe, be ſo looſely ſtretched, that after touching it one may count the Vibrations, it will never produce any Sound. Even if it be ſtretched a little more powerfully, it will not properly afford a Sound, ſo long as the alternate Vibrations of it can be enumerated. But when it has been ſo far ſtretched as to vibrate ſeveral hundred times in the Space of a Second, it will then by ſtriking yield a grave Tone, which will by Degrees become more acute, as it is more powerfully ſtretched; inſomuch that when the tenſe Chord is near upon breaking, it yields a moſt acute or ſhrill Tone. From theſe Conſiderations it follows, that Sound is a tremulous Motion of the Air, excited into ſuch quick Vibrations, as to go and return ſo many times in the Space of a Second, as are reckoned in the Memoirs of the Royal Academy at *Paris*, *ann.* 1700. *p.* 172. If there are more than the largeſt Number of Vibrations there limited in the Space of a Second, namely, 6400, it will not produce

the Idea of Sound in us; if there are fewer Vibrations in the ſame Space, namely, than $12\frac{1}{3}$ in a Second, we ſhall not then be capable of perceiving any Sound, although there may be other Animals to which ſuch a Sound may be audible enough.

Bells are uſually caſt of the moſt elaſtic of all Metals; for ſoft Metals, ſuch as Lead do not yield any Sound. A Bell formed of ſuch elaſtic Metal may be divided in the Imagination into Circles or Sections, which while at reſt, are equally diſtant from the Center; but when any Impulſe, though ſmall, preſſes more upon one Point of the Periphera than upon another, the Figure of the Circles which compoſe the Bell will be changed into an Ellipſis, as is apparent to the Eye, and as may be demonſtrated by tying a Thread round the Bell. But ſo ſoon as the Stroke is removed from the Bell, it not only continually returns into a Circle, but its Sides recede beyond the Circle, ſo as to form an Ellipſis greater than a Circle; and therefore the whole Bell has a Body, all the Sections of which are Circles continually changing their Figure into an Ellipſis, and of returning again into that of a Circle. By this Receſſion and returning of the Sides of the Bell, the ambient Air is conſequently obliged in like manner to paſs to and from the ſame; ſo that if the Bell be left to itſelf for a few Seconds of Time after it has been ſtruck, it continues to ſend forth a Tone by the continual Tremor of its Sides agitating the Air; which Tone would not be audible if the Tremor was ſuppreſſed by applying the Hand.

[6] The ſonorous Body is that which ſo changes the Air, as to produce Sound. For the Sound is not in the Bell which we ſay rings, but in the Air which the Bell itſelf agitates by its alternate tremulous Motion of contracting and dilating, by which you

you may perceive ſmall Grains of Sand to be ſtruck off, as well as the Particles of the Air by the tremulous Motion of the Bell, which being compoſed of elaſtic Metal, is changed from a Circle to an Ellipſis by the Stroke, which may be demonſtrated even to the Eye itſelf, and by tying round a Thread. But then this Ellipſis does not continue, becauſe the Elaſticity of the Metal reſtores it to its former Circle; after which it returns again to the Ellipſis, and ſo to the Circle again alternately, ſo as to compreſs the contiguous Air, and cauſe it to flow from and return back again to its Surface. But if the Hand is ſuddenly applied or preſſed upon the Bell after it has been ſtruck with a Hammer, theſe alternate Incurſions and Excurſions of its Sides will be ſuppreſſed ſo as to deſtroy the Sound, which would otherwiſe have continued for three Seconds, if the Hand had been kept off from it.

[7] From which Center the Sound is diffuſed or propagated as from the Center of a Circle by equal Radii, at the ſame time towards every Point of a Sphere. By the Propagation of a Sound we mean, that when the ſame Sound which was heard in the Place A, ceaſes to be any longer heard there, paſſing on to the Place B, where it becomes audible, *&c.*

[8] Let us ſuppoſe a Circle deſcribed, of a Mile diameter, in the Center of which is the Bell; and let us ſuppoſe the whole Periphera, or Circumference of the Circle, beſet with the Ears of healthy People; in that Caſe every Perſon will certainly perceive the Sound of the Bell equally diſtinct, and exactly at the ſame time. But now let us ſuppoſe a Wall erected againſt one Side of the Bell, the Sound will be thereby repelled; and at ſome Diſtance from the firſt Wall, let another be

erected higher than the former: in that Caſe the Sound will not be heard in the former Place, but only in that Part to which it is determined by the Reflexion of the Wall. Theſe Facts are eaſily proved by Experiments, namely, that Sound is propagated in right Lines every way from the ſonorous Point or Center, in the ſame Manner as Light which is emitted in Rays from a luminous Body.

9 When the Preacher ſpeaks in the Pulpit, the Audience who attend to the Sermon, do not hear the Voice of the Preacher ſimple or uncompounded; but they hear the Voice after it has ſuffered an infinite Number of Reflexions from the Roof, Pavement, Walls, and every other hard Body in the Church: and from hence ariſes an infinite Number of Echoes, all which are not diſtinguiſhed from the firſt original Sound. Hence it is that an Oration in a Church which is walled, is more diſtinctly perceived; whereas the ſame would be very weak and hardly audible, if it was delivered to the People in an open Field. For an Echo by reaſon of the continual Succeſſion of Sound, will return the ſame moſt diſtinctly, when the Wall is five hundred Feet diſtant from the Mouth of the Perſon who is ſpeaking; ſo that the whole Interval of the Paſſage of the original and reflexed Voice, may anſwer to a Second of a Minute: but if the Wall ſtands at half the forementioned Diſtance it will indeed repeat the Sound, but then the reflexed Sound will continually follow the Original; and if the reflecting Obſtacle is ſtill nearer to the Mouth of the Speaker, in that Caſe the Echo will not be perceived, but mixing itſelf together with the Voice of the Perſon ſpeaking, will render the ſame ſtronger. And therefore the Voice of a Preacher will be obſcure and weak if alone,

alone, but ſtrong when accompanied with an infinite Number of reflected Voices: and in the ſame manner when a muſical Chord is ſtruck in the open Air, it affords little or no Sound; but if the ſame Chord is ſuſpended in the middle of a hollow Tortoiſe-ſhell, it will afford a ſtrong Sound. In ſearching after Plants in ſtormy Weather, among the ſandy Mountains of *Holland*, I have heard the roaring of the Sea reflected from the Mountains; but upon going down to the Vale, it gave me not a little Surprize to find myſelf encompaſſed on all Sides with a moſt profound Silence. When I aſcended again to the next Hill, the former Noiſe was again audible, ſo long as the roaring of the Sea reflected by the Mountains could reach the Ears of a Perſon ſtanding upon an Eminence or high Place; but ſo ſoon as one is arrived to a Part of the Vale encloſed on all Sides by the Hills, ſo that the adjacent Sound cannot be reflected from them to the Ears, in that Caſe the roaring of the adjacent Sea becomes not at all perceptible.

10 The Rays of Light are propagated or ſpread with ſo great a Velocity, that their Succeſſion may be eſteemed as nothing with reſpect to Time; though the Velocity of it is eſtimated by the celebrated *Roemure*. But Sound moves with a much leſs Velocity; for it is found by Experiment that Sound runs over near a thouſand *Engliſh* Feet in a Second of Time, and not being accelerated in its Courſe it paſſes through ten thouſand Feet in the ſixth Part of a Minute, ſuppoſing the Air to be calm in the Night-time, while the Experiment is performed by three Perſons in a Plain, one of which being armed with a Gun, and the other ſtanding with a Pendulum, while the third being a thouſand Feet diſtant carefully attends to the Light and to the Sound of the Gun. So ſoon as

the Brightneſs of the Gunpowder is perceived, a ſecond and a third Vibration of the Pendulum will paſs before the Sound begins to be heard, which will be in the third Vibration of the Pendulum. It is found by comparing the Numbers of both Obſervers, that the Light was perceived by both at the ſame Inſtant of Time, but that the Noiſe or Sound came three Seconds of a Minute afterwards. This Celerity of the Sound is ſufficient for the Security of human Life; for all Sounds which require our Attention come from adjacent Bodies, and the Succeſſion of Time is ſo ſmall as to be ſcarce perceptible, when the Diſtance is leſs than a thouſand Feet. But if we perceive more Sounds and from more diſtant Parts, they are confuſed by the Multitude and Reflexion of them. But Light comes from a Diſtance almoſt infinite, and if that was to take up ſo much Time in its Paſſage, we ſhould not be capable of making any Obſervations in the Heavens. See N°. 4.

" Several Experiments were made with regard to this by the Grand Duke of *Tuſcany*. He choſe out one of the moſt plain Parts of his Country, and diſpoſed Obſervers at known Diſtances, who diſcharged Guns loaded with different Quantities of Powder. Others were placed alſo with Pendulums, the Vibrations of which they numbered betwixt the firſt Appearance of the Light and the Sound following; by which means they found that the Report of a Gun charged with a great Quantity of Powder, extended itſelf in the ſame Time to a great Diſtance, (as for Example, ten thouſand Feet) with the Report of a Gun charged with a ſmall Quantity of the ſame Powder; ſo that there aroſe no Difference in the Velocity of the Sound from the Strength of the Report: nor did the Pendulum vibrate oftner betwixt the Flaſh

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and Report of a Hand-gun, than betwixt the Light and Noiſe of a Cannon carrying a Ball of thirty-ſix Pounds. It is therefore evident that a large and a ſmall Sound are propagated with equal Celerity; and therefore it is not in the Power of Man to increaſe the Velocity of Sound. In the ſame manner a Stone flung into ſtagnant Water excites it into circular Waves, which move with the ſame Celerity whether the Stone was thrown with a ſmall or great Force. Theſe Waves ariſe becauſe the Stone depreſſes the Surface of the Water upon which it ſtrikes, by which means the adjacent Water is raiſed above the Surface of the reſt, in proportion to the Depreſſure made by the Stone; but the next Moment the Wave of Water which roſe above the Horizon deſcends and is ſucceeded by another circular Wave, *&c.*

[12] If a Perſon diſcharges a Gun in the middle of the Night upon a Plain; and if from that Perſon another is diſpoſed at the Diſtance of a thouſand Feet with a Pendulum towards the South, when the North Wind blows, and another Perſon is likewiſe placed with a Pendulum at the ſame Diſtance towards the North, in ſuch a manner that the three Obſervators are placed in the ſame Line of Direction with the Wind: in that Caſe by counting the Vibrations of the Pendulum betwixt the Flaſh and the Report, the ſame Number of Vibrations will paſs betwixt the hearing of the Sound, as well with the Perſon who is placed with the Wind, as with the other Perſon who is oppoſite to the Wind. Whence it appears that Sound is not accelerated or retarded by the Wind. The ſame Succeſs has been obſerved from the like Experiments repeated twenty times, and even at

greater Diſtances, as, for Inſtance, at the Diſtance of three *Italian* Miles; inſomuch that the Sound could never be obſerved accelerated one Vibration of the Pendulum by paſſing with the ſtrongeſt Wind, nor yet retarded one ſingle Vibration by the Oppoſition of the Wind. That Sound ſhould be thus diſpoſed to ſpread itſelf equally was neceſſary to the Advantage of human Life. Nor is it at all difficult to explain this ſeeming Paradox. *Mariot* has calculated the greateſt Velocity with which a Wind ſeems to run, and found it to be ſlower than is commonly thought, even at a time when it was ſtrong enough to blow down Houſes. In the ſame manner a Lad can eaſily keep Pace with the Waves of Water moved with a great Impetus. The Wind therefore having ſo ſlow a Motion, cannot much alter the Courſe of the more ſwift Sound in ſo ſmall a Diſtance as to be audible to our Ears: but for greater Diſtances the Experiment cannot be made, becauſe the Incurvation or globular Figure of the Earth will not admit the Obſervators to be placed at greater Diſtances in a right Line. But by theſe Experiments it is found, that the Power or Strength of a Sound is diminiſhed by an oppoſite Wind; whereas thoſe who hear a Sound brought with the Wind, do not hear the ſame ſooner though they hear it ſtronger than thoſe who are placed in an oppoſite Direction to the Wind, who hear it weaker.

[13] The undulatory Motion of the Air communicates its Tremors to elaſtic Bodies, which Tremors become audible when thoſe elaſtic Bodies are ſonorous. If the Undulations of the Air make any Quantity of Sound which is one Octave more grave than the Tone, which would ariſe from the ſame Sound that might have followed from the ſonorous Body, if it was ſtruck without a Medium;

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in that Caſe the Tremors of the Air will excite Tremors in that Body, even though they do not come into contact with the ſame. For Example, take a muſical Chord of two Feet in Length, and take another Chord of a Foot long, but of the ſame Size and Make, and ſtretched by the ſame Weight to an equal Degree of Tenſion; and in that Caſe the Tone of the longer Chord may be termed an Octave lower than the ſhorter Chord, which may be ſaid to be one Octave higher, as the other may be ſaid to be lower. If now the longer of theſe Chords is ſtruck, the ſhorter one will ſound even though no Alteration be made in it, and will yield a Tone one Octave higher than it naturally yields; which may be diſtinctly perceived by the Ear, by ſuddenly ſtopping the Tone of the longer two Foot Chord, while that of the one Foot continues to ſound. Again, let there be another Chord of half a Foot in Length, and ſtretched as before; the whole Length of it will ſound and tremble, if either the two Foot or ſingle Foot Chord is ſtruck; and if the Chord of two Foot long is ſtruck, both that of the one Foot and of the half Foot will tremble and ſound. And in general every Chord whoſe Tone is one Octave, a fifth or a third greater or leſs in Gravity, that Chord will cauſe a Tremor in ſimilar Chords which ſound an eighth, a fifth, or a third greater or leſs but more acute. From hence we infer that a ſimple and pure Sound is never heard; for there is no Place which does not reflect Sound, which wherever produced, is accompanied with a Tremor of all Bodies which yield a Tone above an Octave, fifth or third greater or leſs, and of their Octaves *ad infinitum*; all which ſecondary Sounds are confounded or mixed into one, ſo as not to be ſeparable or diſtinguiſhable by our Ears.

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In the ſame manner in one Tone or Note upon muſical Inſtruments, there are contained an infinite Number of others; namely, all the Octaves, fifths, and greater or leſſer thirds with all their Octaves which tremble together with the Chord or other Body which yeilded the firſt original Tone. Even if a Perſon was to mount upon a flying Horſe, like *Bellerophontes* above the Cities and higheſt Mountains, in order to diſcern what a ſimple Tone or Sound is in itſelf; even then he would be deceived, for the acceſſary Sounds of the Horſe and his Rider would mix with and be reflected together with the ſimple Sound.——This Sound compoſed of an infinite Number of others, ſo as to be hardly explicable by any mechanical Laws, is the Object of hearing. I have endeavoured with infinite Labour to aſcertain univerſal phonergic Laws, but after being involved for the Space of two Years, the Difficulty attending the Subject hardly allowed me to make any Progreſs.

§. 548. Hence therefore we learn that the *ſmooth* [1] Membrane of the external Ear, anointed in its external Cavity with a *Liniment* [2], but almoſt without any *Fat* [3], is firmly ſtretched upon a thin elaſtic and tremulous *Cartilage* [4], which adheres by a cartilaginous Baſis to the Os temporale; ſo that being thus in a State of Tenſion, it receives and ſtrongly reflects together the ſonorous Rays without ſuffocating or *changing* [5] them.

[1] This ſmooth Membrane is neither looſe nor fluctuating, but tenſe and poliſhed without any Wrinkles; and by that means is well adapted to receive and reflect together the ſonorous Rays, which

which are not at all loſt or ſmothered by the ſmall Hairs growing in this Membrane; for Hairs are the moſt ſonorous of any Bodies: and thus *Kircher* has obſerved, that the Leaves of the Trees in a Wood reflect an agreeable Echo which cannot be perceived in the Winter, when the Leaves of the Trees are fallen off.

[2] This Liniment is formed in Cryptæ or Cells, which tranſude an oily Cerate to preſerve the Membranes of the Ear in a due State of Tenſion; which Membranes would be deſtroyed if they were to grow dry, in the ſame manner as muſical Chords periſh if they are not defended with Oil or Reſin. That this Oil is perpetually ſeparated or prepared in this Membrane is evident, ſince if the Ear be rubbed a hundred times in an Hour with a Piece of black Velvet, there will be continually new Sordes wiped off, and viſible to the naked Eye upon the Velvet.

[3] Under this Skin even the moſt corpulent People have no Fat, which would have ſuppreſſed the Reflexion of the ſonorous Rays by the ſubjacent Cartilage, if it reſided there but in the ſmalleſt Quantity. This we ſpeak with regard to the Wing of the external Ear without including the Lobe.

[4] The Ear is at Liberty on all Sides, and faſtned to one Side of the Head by the Intervention of a tremulous Cartilage: that is to ſay, one of the moſt elaſtic Parts in the Body, namely, a Cartilage is conjoined to one of the hardeſt Parts, the temporal Bone, ſo as to produce an Organ the moſt apt to reflect or return ſonorous Rays together.

[5] Which ever way the Head is viewed, either one Ear or the other always offers itſelf to the Sight; nor does it matter much whether you look either

either before or behind or ſideways. In whatever Courſe therefore the ſonorous Rays extend to the Head, they muſt neceſſarily reach the Ears on one Part or the other, which being elaſtic Cartilage will reflect into the Ear many ſonorous Rays which come from Points trembling with thoſe external Sounds, or their eighths, fifths, or thirds, by which new Sounds being produced will increaſe the original Sound (§. 547.). Hence therefore we are furniſhed with two Ears; for if we had but one many of the ſonorous Rays would be loſt; and hence thoſe People who have loſt the Uſe of one Ear, are obliged to move their Head different ways, to take in the Sounds which come from every Side.

§. 549. But in the Figure of the external Ear, there are many Particulars which deſerve to be remarked: ſuch as its conſiderable Eminence, being raiſed on each Side above the Os temporale, by which ſcarce any ſonorous Rays can eſcape either one Ear or the other; and its three *ſpiral* [1] Ridges or Folds, which by their Fabric, Poſition, and Courſe, being inclined, intorted and meeting together, occaſion the ſonorous Rays emitted from any Point to be received by one of the Ears or by both in a ſufficient Quantity, where being *reflected* [2] without Alteration they are then united together, and drove through the external Concha or Shell-like Cavity in the Wing of the external Ear.

[1] Theſe ſpiral Ridges with which the human Ears are furniſhed, ſupply the Deficiency of their Motion, which we obſerve to be much greater in the

the Ears of other Animals. For in every human Ear there are three ſpiral Ridges or Eminences of the Cartilage diſpoſed in ſuch a Curve, that there is a free Paſſage from one into the other, ſo as to reflect the ſonorous Rays from the exterior Zone or Ridge to the interior, from thence into the third, and from thence again the Rays are determined into the Concha. The Ears are thus formed, becauſe they are not erected perpendicularly; for if they were ſo framed by Nature, they would reflect the ſonorous Rays out again from the Ear; but by this Inclination of the Ridges towards the internal Cavity of the Ear, the ſonorous Rays which fall upon them, are directed inward to the auditory Paſſage. I took off the Impreſſion or Figure of the Ear in Wax from a Perſon who had that Senſe in the greateſt Perfection; and to my Surprize I obſerved, that if a Line was drawn from any ſonorous Point to any Point of the protuberant Cartilage in the external Ear comparing it with a right Line, the Angle of Reflexion meaſured equal to the Angle of Incidence, and that the laſt Reflexion always fell upon the auditory Paſſage after many and often repeated Incurſions, ſo that the common Focus of the Curves deſcribed by the Eminences falls in the auditory Paſſage. I once made it the Buſineſs of a whole Year to explain this beautiful Theory. The ſame Fabric was alſo imitated by *Dionyſius* the *Sicilian* Tyrant in the building of his Priſon; for he made it perfectly ſpiral, and placed the Priſoners in the Center of the Spire, by which means the Words which they ſpoke with a low Voice were capable of being heard as if they had talked aloud. But the Ears of Brutes have not theſe ſpiral Eminences, but inſtead thereof their Ears are moveable. In the Horſe and moſt Quadrupeds, the Ear reſembles

ſembles an oblique Section of a Cone, ſo as to admit only the Air in their Fore-part. But the Horſe and other Brutes being provided with Muſcles, are capable of directing their Ears every way at pleaſure towards that Quarter from whence the Sound comes, that the Animal may be capable of hearing more diſtinctly any obſcure Sound. Even in general it is a Rule, that Animals which have ſpiral Ridges in the Cartilages of their Ears do not move them, and the Reverſe; except ſome few Perſons who, like *Midas*, have ſuch a Motion in their Ears. Add to this, that in Man the Head is extremely moveable, ſo that he can readily turn it upon the ſlighteſt Occaſion towards any Sound which requires his Attention.

[2] I muſt confeſs my Opinion to be different from that of moſt Writers, concerning the Reflexion of Sounds. For it is commonly ſuppoſed, that all Sounds indifferently may be reflected from any opake Body. But I am perſuaded that the Number of Sounds are definite and determined by the Creator of all things. But theſe definite Sounds falling upon ſuch Bodies which agree with the Tenſion of that Body which gave Riſe to the Sounds, occaſion ſimilar Tremors in thoſe Bodies, which is what we uſually call a Reflexion of the Sound. Hence therefore among harmonical Bodies, one of a lower Tone never trembles with a Body of a more acute Tone. But if you enquire for the Reaſon, why ſome Bodies ſound together, and others do not at all tremble; it is to be derived from the Number of Undulations which are formed in a given time. We ſay two Chords are harmonical, if the Number of their Vibrations in a given time is the ſame in each; and the next moſt perfect Harmony after an Uniſon, is that which has more than half as many more Vibrations

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in the ſame time, namely, an Octave higher than the former, *&c.* Hearing then is an harmonical Vibration or Trembling of our Ear, ſtruck with the ſonorous Body.

§. 550. But the *Opening* [1] of this concous Cavity, being elaſtic and free on all Sides, is furniſhed with two or three *Muſcles* [2] behind, with one broad above, and a thin one *before* [3]; by the Action of which Muſcles the Concha may be flattened, expanded, ſtretched, and adapted to receive the ſeveral Tremors which produce Sound; and it is ſo diſpoſed, that it can more cloſely unite the ſonorous Rays, or elſe diſperſe and ſcatter them, ſo as to moderate a ſtrong Sound, and increaſe a weak one, as there is Occaſion.

[1] This Aperture is the Beginning of the internal Part of the external Ear. For the Organ of Hearing conſiſts of two Parts, the one external, deſcribed before (at §. 549.) together with the Meatus Auditorius (§. 551.) and the Membrane of the Tympanum (§. 552.); but the internal Ear receives Sounds from the external as through a Funnel, by an Aperture which is commonly called the Meatus Auditorius; but the internal Ear is compoſed of the Cavity of the Tympanum with the Caverns of the Os Petroſum, namely, the ſemicircular Canals and the Cochlea.

[2] The poſterior Muſcle of the external Ear is threefold, but moves only the Concha, and preſſes the ſame backward, ſo as to dilate the Way to the auditory Paſſage. When this Muſcle is relaxed, the Cartilage of the external Ear reſtores itſelf by its own Elaſticity, by which the Concha

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is again contracted: and thus the Cavity of the Concha is enlarged or diminiſhed, according as the Variety of Sounds require.

[3] This anterior Muſcle contracts the Concha, antagonizes the former, and aſſiſts the Elaſticity of the Cartilage of the external Ear. This elaſtic Nature of the Concha has been clearly obſerved by *Valſalva* and *Morgagni*.

§. 551. The Meatus Auditorius is a *Tube* [1] compoſed partly of Cartilage and partly of Bone, lined with a *Membrane* [2] like that before-mentioned (§. 548.) becoming gradually thinner, is extremely nervous, and defended with a viſcid Water and *Wax* [3] tranſuding from the ſubjacent Glands, whence it is extremely well adapted to convey Sounds from without inward without changing or *corrupting* [4] them; but the Obliquity of this Canal increaſes its *Surface* [5], and multiplies the Points of *Reflexion* [6]; alſo a cartilaginous triangular *Tongue* [7] ſtands erect and tremulous in the Cavity of the Concha, and more eſpecially oppoſite to the Entrance of the Meatus Auditorius, and being furniſhed with a proper Muſcle, it by a wonderful Mechaniſm conduces to determine all the ſonorous Rays which fall upon the Concha, to enter the auditory Paſſage without flying back again, being reflected inward on all Sides. The Figure of this Paſſage is tubular, in part cylindrical and part elliptical, aſcending and deſcending in a ſerpentine Courſe, and again ariſing, it terminates in the Membrane of the Tympanum, ſerving

ſerving to increaſe the Reflexion of Sounds, and determine all the collected Rays to fall in the middle Center of the Tympanum without any ſenſible claſhing.

[1] It is in reality a Trumpet or phonergic Tube, ſonorous, narrow, elliptic, conical or conoide, being a hollow Body, a Section of which is an Ellipſis. Part of this Tube is the broad cartilaginous Ear, but the auditory Paſſage is that Part which increaſes the Power of the Sound, lined with a Cartilage which is extremely well adapted to reflect Sound (§. 548.)

[2] The Skin which lines the external Ear is extended by degrees into the auditory Paſſage, expanding itſelf with the Canal ſo as to form a Sack equal to the auditory Paſſage itſelf; but by degrees becoming thinner, is very fine where it covers the external Surface of the Membrane of the Tympanum. It is not only very tenſe, but alſo very thin and nervous, inſomuch that no Pain is more intolerable, than when an Inflammation invades the Meatus Auditorius; for then the numerous ſmall Nerves which are here naturally very tenſe, are yet more diſtended by the inflammatory Tumor ſo as to be ready to burſt, and produce the moſt acute Pain.

[3] The ceruminous Glands of the auditory Paſſage were firſt deſcribed by *Du Verney*. For when that Anatomiſt removed the exterior Membrane of the auditory Paſſage, there appeared in the oppoſite Part very ſmall oblong Cryptæ or Cells, which contained a pellucid and ſomewhat oily Water, which tranſuding through the open Ducts of the Cryptæ into the auditory Paſſage, is there by Warmth and Stagnation digeſted and inſpiſſated

into an yellow and bitter Wax, as we extract it from the Ear, though it has no ſuch Bitterneſs at its firſt Secretion. The Uſefulneſs of this Liniment in defending the ſenſible Membranes of the auditory Paſſage, is very great and almoſt incredible. If the Ear is entirely deſtitute of this Liniment, the internal Membrane becomes dry, rigid and diſtended ſo as almoſt to break the Nerves, and be not far from producing a perfect Deafneſs. So long as this mild Liniment defends the ſenſible Membranes from the Air, they all continue flexible and perform their proper Offices; but when it is collected in too great a Quantity, the ſhort Hairs of the auditory Paſſage having their uſual Increaſe ſuppreſſed by the reſiſting Liniment, are incurvated inward, and irritate the ſenſible Membrane of the Meatus Auditorius, whence follows an Itching, which obliges the Perſon to pick his Ear; but brute Animals from the ſame Cauſe rub their Ears againſt Timber or Stones that are next adjacent. Without this Precaution Deafneſs might enſue: So great is the Uſefulneſs of theſe ſmall Hairs. But this kind of Deafneſs may be cured by injecting Water mixed with a little Soap and Sal Ammoniacum, by which the retained Wax being ſoftened is diſcharged in the Form of a Tent.

[4] It is demonſtrated by the Laws of Sound, that it diffuſes itſelf every way from the Mouth of a Perſon ſpeaking, or from any other Inſtrument, ſpreading itſelf to all Sides in right Lines, which reſemble the Radii of a Circle. The Ear therefore of any Perſon which is placed within the Area of this Circle or Sphere of the ſonorous Rays, will receive ſo many of them as can be contained in a Cone, the Baſis of which is the external Ear, and its Apex the ſonorous Point; while the other Rays eſcape or fall off from the Side of the

the Ear. But the Strength of Sound depends upon the Number of ſonorous Rays which are contained in a given Cone. If now we form a Machine which can receive a great Number of ſonorous Rays, reflect them together, and afterwards direct them into a Focus; then the Strength of the Sound will be increaſed in that Focus, in the ſame manner as the Force of Fire collected by a convex Glaſs, is increaſed in the Focus; and by this means the ſmalleſt Sound may be ſo changed as to affect the Senſe of hearing, in the ſame manner with the ſtrongeſt. Of this Nature is the Speaking-Trumpet, which Inſtrument is compoſed of a narrow Part applied to the Mouth, from whence it ſpreads into a diverging Cone, whoſe elaſtic Sides receive the whole Sound which comes from the Mouth: but the ſonorous Rays are reflected by the elaſtic Sides of the Inſtrument, and the Angles of Reflexion being equal to the Angles of Incidence, after many Reflexions the ſonorous Rays paſs out into the open Air, not diverging but parallel. By this means the Sound of a Voice may be ſo increaſed, as to be heard at the Diſtance of a Mile and a half by a Perſon who is in a right Line; for thoſe who are on either Side perceive nothing of the Sound; which if it had been emitted from the naked Mouth, would have been loſt at the Diſtance of a few Paces or Ells. Even leaden Pipes which are not elaſtic and only cylindrical, do yet reſerve the Sound of the Voice, that when a Perſon ſpeaks at one End, it may be perceived by the Ear applied to the other End, even at the Diſtance of a quarter of a Mile. But ſuch a Tube or Trumpet as that before-mentioned, is the Meatus Auditorius in an adult Perſon; for in an Infant that has not been long born, this Paſſage is little or nothing, the Membrane of the

Tympanum being placed immediately behind the Ear, and covered over with a thick ſcaly Matter or Skin; which by the receding of the Membrane of the Tympanum backward, and the Elongation of the auditory Paſſage is caſt off by a kind of Suppuration. The longer the Animal lives, the Membrane of the Tympanum recedes the farther back, and the Meatus Auditorius is alſo more elongated. This Covering upon the Membrane of the Tympanum was neceſſary in Infants, that they might not be continually affected by the Action of ſtrong Sounds, by which their tender Nerves might be eaſily convulſed. It is therefore a deteſtable and unhappy Practice, in thoſe who endeavour to divert young Infants with the Noiſe of Guns, and ſhewing them ſtrong Lights, by which the whole Brain and nervous Syſtem may be put into Tremors, to the Deſtruction of the unhappy Infant. But if Wax is poured into the Ear of an adult dead Body, and afterwards taken out whole when it is cold, by dividing the Bone without injuring the Figure of the Wax, you will have a perfect Trumpet, whoſe Extremity is without any Aperture towards the Membrane of the Tympanum.

[5] The Meatus Auditorius could not deſcend very deep into the Cranium, for it would have penetrated its Cavity and the Brain; and therefore to render it the longer and increaſe its Surface, it was neceſſary for it to be oblique. But long Tubes eſpecially thoſe which are contorted, wonderfully increaſe Sound; thus the *French* Horn which is ſpiral, gives a very ſtrong Sound; and Trumpets for War ought to be very long in order to afford a ſtrong Sound. But leſt their great Length ſhould render them incommodious, they are inflected or folded together, that the long Tube may be

be contained in a ſmall Compaſs. The Deſign is almoſt the ſame with reſpect to the Obliquity of the auditory Paſſage, which firſt aſcends then deſcends, and afterwards aſcends a little again; ſo that its ſmall Depth is compenſated by the greater Obliquity. But all theſe Rays which are directed by the external Ear to the auditory Paſſage, meet together at laſt without Alteration in a Point, namely, upon the Membrane of the Tympanum, which ſhuts up the Meatus Auditorius of an elliptic Figure like the Paſſage itſelf; the Focus therefore of the ſonorous Rays falls upon this Membrane, upon which the whole Strength of the Sound is concentrated, which was conveyed thither by the external Ear. This reſults from the Properties of an elliptic Tube. At the Court of *Tuſcany* there is an elliptic Portico, in which if a Perſon ſpeaks againſt the Wall with a low Voice, every Word that he whiſpers will be heard diſtinctly by a Perſon who ſtands in the Focus of the Ellipſis, while thoſe who ſtand without the Focus hear nothing at all.

[6] The Writers upon philoſophical Subjects are the moſt ſurpriſed at this Phænomenon, namely, that we ſhould hear a ſimple Sound, which yet is demonſtrated to be compoſed of an infinite Number of other reflexed Sounds. For Sound is reflected a thouſand times from one Side to the other of the auditory Paſſage, as well as in a Trumpet, till at laſt it converges together into a Point, and continues ſtrait forward, as if it came from that laſt Point. But all theſe Sounds are repreſented to the Mind as but one. Muſic will be able to remove all theſe Difficulties: for it is moſt true, when we ſpeak, or when any Inſtrument excites a Sound, there follows an infinite Number of Reſonances or Echoes; but yet thoſe Reſonances are

not in the leaſt diſtinguiſhed by the Ear, which preceives only the ſingle Tone. For an Echo is not diſtinguiſhed unleſs it returns from a certain determinate Diſtance. If a Wall is a thouſand Feet diſtant from the Mouth of the Perſon ſpeaking, one may then hear the Return of each Word, or as it were the Image of the ſame, which we call an Echo; for the Sound paſſes in one Second of Time to the Wall, and in another returns again, ſo that there is time enough for one to diſtinguiſh the returning from the primitive Sound. If now the Diſtance of the Wall be diminiſhed, ſuppoſe at the Diſtance of an hundred Feet, and then to the Diſtance of ten Feet, in that caſe the Time of the Paſſage of the primitive and reflected Sound to and from the Wall is ſo ſhort, that the Idea of the former is not out of the Mind when the latter returns; for the Images or Ideas of Objects impreſſed upon the Senſory do not always inſtantly vaniſh, nor do we diſtinguiſh thoſe which follow each other moſt nearly (§. 541.) Therefore the reflected Sounds are all of them conjoined with the primitive, ſo as to afford the Idea of one ſingle Sound. I ſaid before at §. 547, that the Chord B is in Harmony with the Chord A, and will tremble together when A and B are diſtant one Octave. If two ſuch Chords ſound together, we hear but one Tone, becauſe the greater and the leſs of the ſame Kind are confounded together ſo as to be indiſtinguiſhable. In the ſame manner in our hearing, all Sounds which ariſe from Bodies in Conſonance with the primitive Sound, are joined together into one, ſo as not to be diſtinguiſhable from the primitive Sound with which they agree. If this was not true, we ſhould have been certainly created unhappy by Nature, ſince inſtead of one Sound we ſhould hear an infinite Number of Diſcords, or diſagreeable Claſhings of Sound. But by the

the former, that is, by the Vicinity of the reflected Sounds, Nature has ſecured our Hearing from being diſturbed by Echoes; and by the latter, that is, by the harmonical Conſonance, we are ſecured from the diſagreeable Tremors and Claſhings of the Air.

[7] At the Beginning of the Meatus Auditorius is placed a tremulous triangular Body, with which the whole Aperture of that Paſſage may be cloſed, ſo that a Man cannot be able to hear any thing with that Ear. This triangular Body or Tongue is capable of being erected more or leſs by the ſmall Muſcles of *Valſalva*, ſo that we may be able to moderate the Opening of the auditory Paſſage at pleaſure, leſt when the ſonorous Rays arrive to the Ear in too great a Quantity, they might deſtroy the Organ of Hearing; whereas by diminiſhing the Aperture, Part of the too powerful ſonorous Rays are excluded. The Action of this Part or Safeguard to the Ear is perceptible to the Eye without Difficulty, when after ſeeing the Flaſh of a great Cannon we prepare our Ears to receive the great Shock and Noiſe that is to follow. But this Part which is called the Tragus is furniſhed with another Muſcle antagonizing the former, by which the Tragus is drawn outward, ſo as to enlarge the auditory Paſſage, when we endeavour to hear any Sound accurately and diſtinctly.

§. 552. The *Membrane* [1] of the Tympanum is compoſed of three Coats or Lamellæ, the middlemoſt of which is very full of ſmall Veſſels, but the outermoſt of them have ſcarce any Veſſels; and they are placed ſo obliquely, as to incline above towards the auditory Paſſage, and running out from below, forming

an obtuſe Angle above with the Meatus Auditorius, and an acute one below; which increaſes thus the Superficies more than if it was ſpread perpendicularly: by this means there is a larger Compaſs for receiving more ſonorous Rays to fall upon the Tympanum, upon which the tremulous Concuſſions are multiplied; but more eſpecially it determines them to run together into the Center of this Membrane, ſo as to render it more eaſily tremulous: but ſince the exterior Lamella is membranous from the Meatus Auditorius, and the interior Lamella is derived from the Membrane which encompaſſeth the Tympanum, it is evident that this Membrane hath a great *Communication* [2] and Conſent both with the external and internal Parts of the Ear. The middle Coat may perhaps ariſe from the Expanſion of a *nervous* [3] Membrane.

[1] The Membrane that lines the auditory Paſſage recedes inward on all Sides from the Extremity of the ſame Paſſage, and meeting together in oppoſite Parts forms a blind Sack, and by that means cloſes the bony Paſſage. To the Bottom of this Membrane is again applied a Membrane from the Pericranium full of Veſſels, and another from the Perioſteum of the Cavity of the Tympanum. So that the exterior and interior Membrane is derived from the Perioſtea, betwixt which is the vaſcular Membrane. Thus three Membranes concrete together and form the Tympanum, as *Ruyſch* formerly declared to us, though he has ſince made the Tympanum to conſiſt of but two Membranes. I gave him to underſtand that he was

was in the wrong to detract from this firſt Opinion; for all Injections do not ſucceed equally well.

[2] All the Nerves in the human Body communicate together in a ſurpriſing manner. From an Irritation of the Noſe the Diaphragm itſelf is convulſed, and Sneezing follows from the Communication of the intercoſtal Nerve with thoſe of the Neck, which ſend out a Branch to the Diaphragm. In the Glans Penis of a calculous Patient there is an intolerable Itching, becauſe the Stone irritates the Membrane of the Bladder, which is continued through the Urethra, and lines the Glans itſelf. But Tremors and Vibrations are moſt eaſily communicated through Membranes which are ſo very tenſe, and endowed with ſuch an Elaſticity as the Tympanum.

[3] That this Membrane is nervous, we are perſuaded from the almoſt convulſive Pain which follows from an Inflammation of it.

§. 553. The ſtrict Application of this Membrane, the Tympanum, to the *Edges* [1] of the bony Paſſage or Cavity, together with its Thinneſs, Drineſs and Laxity, accompanied with a Concavity towards the auditory Paſſage, and a Convexity towards the Os petroſum, and the Malleus being fixed to it, teach us that this Membrane prevents the Entrance of the *Air* [2] from the auditory Paſſage into the internal Ear; and that Dirt, Humours, Inſects, Duſt, and the like, are here embarraſſed in the Ear-Wax, and exciting a Titillation, chiefly by moving the ſmall *Hairs* [3] which are here ſeated, they are again caſt out; alſo

alſo that the ſonorous Motions or Vibrations may be *tranſmitted* 4 to the Cavity within the Ear; and perhaps ſomething of an obſcure Senſe of hearing may be performed in this Membrane itſelf, namely, the Tympanum.

[1] The whole Circumference of the Membrane of the Tympanum is inſerted to the bony Ring, which has a Deficiency only in one Part, through which paſſes that wonderful Muſcle of *Aquapendens* to the Tympanum, which has been ſince diſcovered and reſtored by *Cowper*. This Inſertion of the Tympanum into the Margin or Sulcus of the bony Ring, keeps it extremely tenſe in the ſame manner as the Parchment is extended upon the muſical Inſtrument of War, which we call a Drum, from whence this Membrane derives its Name, preſerving and augmenting the Sounds which ſtrike upon it. For upon whatever Part the Tympanum is ſtruck, Tremors are conveyed from that Point as through Radii to the Periphera of a Sphere. But yet this uniform Tenſion of the Tympanum is not of itſelf ſufficient for hearing; for if it was only ſtrained to the harmonical Tenſion of one Sound, it would only tremble from that Sound, with its Octaves, Fifths, and Thirds, greater and leſs (§. 547.), ſo that we ſhould not be capable of hearing any more than this one kind of Tone or Sound. It was therefore neceſſary to contrive a Mechaniſm by which this Membrane might be more or leſs ſtrained or tightened, according to the Variety of Sounds, that it might be capable of coming into Uniſon, or correſpond harmonically to all Sounds. In the ſame manner a ſingle muſical Chord will expreſs all Sounds only by different Degrees of Tenſion. For if the

Chord

Chord ſounds lower than is juſt, by ſtraining it a little the Sound will be more acute, and by doubling the Tenſity it will ſound an Octave higher than before; ſo that by only turning round the Screw from one Octave to another, it may be raiſed through all the intermediate Sounds.

2 That the Tympanum performs this Office, we learn from a practical Experiment. If any one is hard of hearing, and applies to a Phyſician to know whether the Tympanum is injured, the Patient is ordered to take a deep Inſpiration, and ſhutting his Mouth and Noſtrils, to make the Effort of Expiration, by which the Cheeks are diſtended with Air, which inſinuates through the *Euſtachian* Tube to the Cavity of the Tympanum; and if that Membrane is broke, it eſcapes through the external Ear, and denotes that the Deafneſs is incurable. But if the Air does not eſcape through the external Ear, being confined by the entire Tympanum, there are Hopes of relieving the Patient. It was neceſſary for Nature to furniſh the Ear with this Membrane, as a Safeguard to the Muſcles, Ligaments, and Perioſtea of the ſmall Bones which are contained in the Cavity of the Tympanum, that they might be kept ſoft, pliable, and fit for Motion, ſuſpended as it were in a vaporous Bath ſecured from Inſects, and preſerved from the Drought of the external Air.

3 Theſe Hairs grow very ſpeedily, and have been deſcribed by *Du Verney*. When they are compreſſed or incurvated, they are thruſt into the Membrane which lines the auditory Paſſage, ſo as to occaſion an Itching which is intolerable to every kind of Animal, and gives them notice to remove the irritating Cauſe as ſoon as poſſible. If Nature had not provided us with this neceſſary Senſe, we might have been eaſily deprived of

of our Hearing without any Warning, as the Huſbandmen frequently are, when the auditory Paſſage is filled full of Duſt; but the Sordes being diſſolved by injecting with a Syringe, the Diſorder is removed.

[4] To tranſmit the ſonorous Impreſſions not thro' an Aperture, but by ſimilar Tremors in the Membrane of the Tympanum, which excites the ſame Tremors in the Air included in the Cavity of the internal Ear. How much Influence Sound has in drawing the moſt ſolid Bodies into ſimilar Tremors, is evident from the muſical Organs of Churches: when the loweſt Pipe of that Inſtrument is blown, it ſends forth ſuch a Tremor or Vibration as in a manner draws the whole Pavement and Pillars of the Fabric into a ſimilar dancing Motion. In the ſame manner large Cannons which are uſed in the beſieging of Cities, ſhake the whole Surface of the Earth to the Diſtance of ſome Miles, ſo as to make a Bullet dance that is placed upon the Parchment of a Drum.

§. 554. The Malleus is *firmly* [1] applied to the Back of the Membrane of the Tympanum, with its Handle extended almoſt to the *Center* [2] of that Membrane; and at the ſame time the Head of this Bone is moveable in the Bony *Sinus* [3], while the other Surface of its Head is furniſhed with two ſmall *Protuberances* [4] and one Excavation, being connected by the Articulation called Ginglimus, with two Cavities and one Protuberance of the Body of the Incus, which is otherwiſe freely ſuſpended in the ſame Cavity by the artificial Inſertion of three Muſcles into this Malleus: here alſo the

the *external* 5 Muſcle which relaxes the Membrane of the Tympanum firſt preſents itſelf, ariſing fleſhy from the upper Part of the Margin of the external bony auditory Paſſage, and is inſerted tendinous, running under the Membrane which is repleniſhed with ceruminous Glands, from whence its Tendon aſcends to the upper Part of the Membrane of the Tympanum, where it paſſes through a Sinus or Deficiency which is left in the Margin of the bony Ring, and enters into the internal concous Cavity; where aſcending even to the Protuberance betwixt the upper and lower Apophyſis of the Malleus, it is there inſerted: from whence it appears that this Muſcle draws the Malleus and Membrane of the Tympanum towards the auditory Paſſage, by which means the Tympanum is rendered ſmooth and lax. 2. In the ſecond place we here diſcover the *external* 6 Muſcle, which ariſing tendinous from the external Part of the *Euſtachian* Paſſage, upon which it lies fleſhy, aſcends afterwards backward and enters the Cavity of the Tympanum, paſſing through an oblique Sinus or Notch, above the bony Margin of the Membrane of the Tympanum, and inſerts itſelf into a ſlender Proceſs of the Malleus, and is particularly extended into a very long, ſlender, flexible and elaſtic Production, which was diſcovered by the laudable Induſtry of *Raw*, who has taught us that this Muſcle is inſerted by a very broad Expanſion of Fibres for an extraordinary Uſe; namely, that it might determine and draw the thicker Part

of

of the Malleus with the Membrane of the Tympanum, in many different *Directions* [7] towards the Meatus Auditorius. 3. In the third place we diſcover the *internal* [8] Muſcle of *Euſtachius*, whoſe Fibres ariſing from the anterior Side of the Cartilage of the *Euſtachian* Paſſage, is afterwards contained in and runs through a bony Furrow, from whence it aſcends laterally to the upper Part of the *Euſtachian* Paſſage; from whence departing, its Tendon riſes up near the Feneſtra Ovalis, and turning back about a bony Part like a Pully, it is inſerted into the Malleus in its back Part, under the Inſertion of the external Muſcle of the ſame Bone; when this Muſcle contracts, the Malleus and Membrane of the Tympanum is drawn towards the Os petroſum, by which means it is tightened and rendered concave: and from all this we learn that the Malleus is like a Lever applied to the Membrane of the Tympanum, and being moveable in a Moment preſſes upon the Sinus or Excavation in the Margin, as being fixed to a Baſis ſuſtaining its Rotation, in which it is drawn by the Contraction of one, two, or three Muſcles; it may therefore, 1. expand or *tighten* [9] the Membrane of the Tympanum, relax the ſame, render it convex, hold ſteady and ſuſpended it in various Degrees of Tenſion and in different Directions. 2. It may alſo by this means vary the internal Space of the concous Cavity, ſo as to draw the Air in, compreſs or expel the ſame according as the *Euſtachian* Paſſage is at the

the ſame time either open or *ſhut* [10]. 3. By this means therefore the Membrane of the Tympanum may be adapted to receive the ſonorous Vibrations or Tremors to be communicated to Bodies *harmonically extended* [11] or ſtretched, and that it may eaſily communicate them to the Incus, as we are taught by the mathematical Doctrine of Harmony or Muſic.

[1] The Malleus is ſo firmly attached to the Tympanum, that its Membrane ſeems to be ſpread over the Proceſs of that Bone, ſo as to include it as it were in a Duplicature. It is to be obſerved that the Moderns improperly call this Membrane the Tympanum, ſince by that Name the Ancients underſtood alſo the whole Cavity of the Os petroſum in which the ſmall Bones are included; diſtinguiſhing this by the Name of the Membrane of the Tympanum, manifeſtly ſo called from its Similitude to the Kettle-Drum.

[2] But it is not extended beyond the Center of this Membrane; and therefore it forms a moveable Radius attached to this Center, that by being drawn inward it may tighten the Membrane, and render it more convex towards the Os petroſum, and relax the ſame, or render it more flat, by thruſting it farther towards the auditory Paſſage.

[3] This bony Sinus is ſeated in that Part where there is a Deficiency in the bony Ring of the Membrane of the Tympanum, in which Sinus the fixed Point or Hypomochlion of the Malleus is ſtationed, upon which it moves and inclines one way or the other.

[4] The Articulation of the Malleus with the Incus is very much like that of the Knee, where the Tibia

Tibia is collected to the Femur, and admits only one kind of Motion. By this manner of Connection it happens, that the Malleus cannot be moved upon its fixed Point without moving at the ſame time the Incus which is freely ſuſpended.

[s] *Fabricius* of *Aqua pendente* firſt deſcribed this Muſcle in an elegant Treatiſe upon that Subject, which is become obſolete or neglected in our Days. It ariſes with muſcular Fibres under the firſt Tunic of the auditory Paſſage, and paſſes through the Deficiency in the bony Ring above the Membrane of the Tympanum into the internal Ear. It draws the Malleus, together with the Membrane of the Tympanum, towards the Meatus auditorius, ſo as to render the latter more flat, when it has been render'd convex or protuberant towards the Cavity of the Tympanum, oppoſite to the auditory Paſſage; from which Action it neceſſarily follows, that the Membrane of the Tympanum muſt be relaxed by this Muſcle. For every Line which unites two Points is the ſhorteſt when ſtrait, and muſt be elongated whenever it is formed into a Curve, while the Points remain at the ſame Diſtance: and, on the other hand, a curved Line joining two Points muſt become ſhorter when reduced to a ſtrait Figure. But a Fibre being elongated is tightened, and relaxed when it is ſhortened; and therefore it follows, that the Membrane of the Tympanum being rendered leſs convex muſt be relaxed, which can be the only proper Action of this Muſcle. So often then as this Membrane is too tenſe to be in Harmony with the more grave Tones, it is then reduced to Uniſon by the Action of this Muſcle, which relaxes the ſame while the other Muſcles are at reſt. Thus thoſe grave Tones will be audible, which a greater Tenſity of the Membrane would not have tranſmitted to the Mind.

Mind. This ſame Muſcle alſo increaſes the Capacity or Cavity of the Tympanum, giving a Paſſage to the Air coming through the *Euſtachian* Tube into the internal Concha.

[6] The firſt of the internal Muſcles ariſes from the Os petroſum, from a Sulcus in the outer and anterior Part of the *Euſtachian* Tube; and after proceeding a little way forward, it aſcends obliquely and enters the Sinus oſſeus; from whence again it paſſes out, and is inſerted by a ſmall Tendon into a Proceſs of the Malleus. When this Muſcle acts, it draws the lower Part of the Malleus, together with the Membrane of the Tympanum to which it is attached, inward and forward, rendering the ſame more convex, and of an harmonical Tenſity with the more acute Sounds.

[7] The ſecond of the internal Muſcles ariſes from the anterior Part of the Side of the Cartilage belonging to the *Euſtachian* Tube, and then paſſing through a ſmall Excavation in the Os petroſum, it runs along laterally to the upper Part of the Opening of the *Euſtachian* Tube; and from thence deſcending perpendicularly, it is inſerted into the ſame Part of the Malleus with the former. When this Muſcle acts, it draws the Malleus and Membrane of the Tympanum directly inward, and tightens the ſame. Theſe two Muſcles when they operate conjunctly, ſtretch the Membrane of the Tympanum in ſuch a manner, that it is ſuſceptible of the leaſt Variation in Motion, and retain it in ſuch a perfect Equilibrium, that it is put into Tremors by the leaſt Vibration of the external Air acting but for a Moment. And thus conditioned is the State of the Ear in thoſe People who are inclined to Muſic; whereas thoſe who cannot thus adapt their Ears to different Sounds, can never make any Proficiency in Muſic. But others continually

ſing the ſame Tone which they hear, and are capable of repeating Songs as faſt as the Eye can take them without any Defect in the Tone.

[8] The firſt of the internal Muſcles is furniſhed with a very long, flexible, and elaſtic Proceſs, of a greater Extent than all the reſt of the Bone, in order that it might be more conveniently inſerted into the Malleus. The Diſcovery of this Proceſs is owing to *Raw*, although it is ſaid to have been demonſtrated and diſcovered by one *Foly* in the Writings of *Bartholin*. But this Muſcle is inſerted the whole Length of the Proceſs, by which means it is capable of moving the Bone and tightening the Tympanum in different Degrees; whereas if it was inſerted into a ſingle Point of the Bone, it could only give it one Degree of Tenſity; but as it ſends forth a long Series of Fibres into the Bone, it may be capable of drawing the ſame, more or leſs, laterally in an infinite Number of Degrees and Directions, according as this or that Series of Fibres ſhall prevail. Others think this Proceſs to be rather a ſort of Bone articulated to the Malleus, and which by Age grows together with the ſame, as we uſually obſerve in the Os ſtyloeides and the Os temporale.

[9] The ſhorter any Chord is, the leſs Degree of Tenſion it requires to produce a Variety of Sounds; but the longer the Chord, ſo much the greater Force it requires to vary its Tone. But in the Ear there are ſmall Fibres inſtead of Chords, which yet may be ſtretched harmonically through different Degrees. As this was neceſſary, the Membrane of the Tympanum is therefore provided with moving Muſcles and Levers, which are capable of tightening the ſame various Ways. All theſe Muſcles are placed by Nature in a Part to which the external Air has no Acceſs. *Euſtachi-*

us

us and *Aquapendens* have demonſtrated, that the whole Cavity in which theſe Muſcles are diſpoſed, is repleniſhed with warm and moiſt Vapours. So ſoon as the external Air penetrates to the ſmall Bones of Hearing by an accidental Rupture of the Membrane of the Tympanum, all the Muſcles are dried up; and inſtead of diſtinct hearing, a confuſed Noiſe is perceived, ſo that the Patient can neither diſtinguiſh articulate Words nor muſical Notes, till at length the whole Senſe is entirely deſtroyed.

[10] When the *Euſtachian* Tube is cloſed, no Air can paſs into the internal Ear; but then the Membrane of the Tympanum is ſtruck by ſome external Sound, and by that means rendered more convex, it compreſſes or condenſes the included Air in the Concha, that the Tremors may be more powerfully communicated to the internal Ear. But when the *Euſtachian* Tube is open, the Membrane of the Tympanum is preſſed out by the Air which entered through the Tube; whence the Air which conveys the Sound through the auditory Paſſage is reſiſted, and conſequently the Perception of it is diminiſhed. The Tube is therefore cloſed or ſhut in order to the more diſtinct Perception of Sounds, but is relaxed and opened in order to diminiſh their Force; whence it appears that the Membrane of the Tympanum is moved, as well by the internal Air as by the external.

[11] A ſimple Percuſſion of the Air, which is a Particle of Sound, being repeated a determinate Number of times by the Tremors of the ſonorous Body, forms a determinate Sound. When theſe Tremors are very ſwiftly repeated, the Tone is ſaid to be acute, but grave when the Vibrations of the Chord are ſlow; for the ſame Chord being moved ſlowly will yield a great Tone, and being put into quick Vibrations, it will alſo yield an

acute Tone. Now when a vibrating ſonorous Body communicates its Percuſſions to the Air, and there is any adjacent Body which by ſome Impulſe will yield the like Number of Vibrations in the ſame time, in that Caſe this other Body will likewiſe begin to vibrate at the Sound of the other, and two ſuch Bodies are ſaid to be in Concord. But if the Body A communicates its Tremors to the Body B with which it is in Concord; and again, the Body B likewiſe communicates its Tremors to that of C with which that is in Concord; then in that Caſe when A ſounds, C will alſo ſound in Conſonance: but when the Body A ſounds by a Stroke, while the quieſcent Body B does not produce the ſame Number of Tremors in the ſame time, in that Caſe, when one Body ſounds the other will not be affected, ſo that the Bodies A and B may be ſaid to be in Diſcord. From hence ariſes the Reaſon why the Malleus is qualified for different Motions by particular Muſcles. For Sounds differ from each other in an infinite Number of Ways, as well in their Kinds, as in the numberleſs Degrees of Gravity or Acuteneſs. Yet ought the Membrane of the Tympanum to be capable of being in concord with all theſe different Sounds, in order to return the like Tremors, and communicate them to the internal Ear, that they may be repreſented to the Mind as they come from without. This Concordance of the Membrane of the Tympanum with the great Variety of Sounds, is produced by the Malleus with its proper Muſcles, which produce an infinite Number of Degrees of Tenſity in the ſame Membrane. The Tympanum then may be determined to all thoſe Degrees of Tone with which the Chords of the Tympanum are in Conſonance. But theſe Sounds are infinite in Number and Variety, which renders this Matter

not

not a little ſurpriſing. The Chords of the Membrane of the Tympanum are very ſhort, the whole Extent of that Membrane being no larger than one's Nail; and yet can thoſe ſhort Chords increaſe the Celerity of their Tremors to produce more acute Tones, ſo that the Membrane of the Tympanum can bear all Tones, which are not more acute than thoſe which ariſe from a Chord equal in length to the Diameter of the Nail. But when any Chord trembles which is ſhorter than the Diameter of the Nail, ſo as to yield more ſwift Tremors than the Membrane of the Tympanum, it then produces a ſqueaking, which affects the Teeth and adjacent Parts ſo as to be almoſt leſs tolerable than Death itſelf, even in Men who have this Senſe duller than uſual, the Membrane of the Tympanum being then ſtretched ſo as to be near breaking: ſuch ſhort Chords as theſe are tenſe Particles of Iron, as when thin Plates of Steel are held faſt betwixt two Screws, and filed away on the Edge, as in making Saws.

§. 555. The Body of the *Incus* [1] articulated to the Malleus (§. 554.) preſſes likewiſe upon the Sinus Oſſeus in the Malleus, its ſhorter Proceſs being freely ſuſpended by a Ligament in the upper and poſterior Part of the Cavity of the Concha; while its longer Proceſs is collected to the *Os orbiculare* [2]; the Articulation alſo of this Bone with the hollow Apex of the Stapes, with the Connection of the elliptic Baſis of the Stapes with the Membrane of the Feneſtra ovalis, demonſtrate that the ſonorous Tremors being impreſſed upon the Membrane of the Tympanum, may be (by the Aſſiſtance

of theſe four Bones encompaſſed with their vaſcular Perioſtea, and connected by their reſpective Articulations, ſuſpended freely in the large Cavity of the Concha, and moiſtened continually by the tranſuding Humours) communicated unaltered to the Membrane of the Feneſtra ovalis, and there make the like Impreſſions.

1 The Incus is furniſhed as it were with two Feet, the former of which is connected by a particular Ligament to a reſounding Cavity in the Proceſſus Maſtoideus. The other Leg of the Incus reſts upon the Baſis of the Stapes, all the reſt of it being at liberty or freely ſuſpended. Hence it follows, that when the Membrane of the Tympanum excites the Malleus into harmonical Tremors, the Incus muſt be agitated in the ſame manner, and communicate the like Tremors alſo to the Stapes. But the Stapes ſtands upon the Membrane which ſhuts the Feneſtra Ovalis of the Tympanum, and therefore that oval Membrane muſt likewiſe ſuffer the ſame Tremors. Nor does the Tremor here ſtop, for the other face of the oval Membrane looks towards or into the Veſtibulum; and into the Veſtibulum open the winding Cochlea and five ſemicircular Canals; and in the Veſtibulum again the pulp itſelf of the auditory Nerve is expanded naked in the ſame manner as the Retina is expanded round the vitreous body in the Eye. A Tremor therefore of the external Air will excite ſimilar Tremors, firſt in the Membrane of the Tympanum, then in the ſeveral ſmall Bones, afterwards in the Membrane belonging to the Feneſtra Ovalis in the Veſtibulum, and at laſt in the auditory Nerve itſelf. But the Tremors are not communicated

nicated in this manner without ſome Addition, for they are increaſed while they paſs through the ſmall Bones. For every body which is in harmony with the Sound that ſtrikes the ſame, will likewiſe regenerate a ſimilar Sound. Thus in a Harpſichord, the ſhrill and vivid Tone does not ariſe from ſtriking one ſmall ſilver Chord, but is owing in a great meaſure to the Concordance of the whole Inſtrument, which ſounds at the ſame time.

[2] One Leg of the Incus which reſts upon the Stapes, is articulated with the laſt mentioned Bone by means of an intermediate ſmall Bone, which like a Meniſcus is hollow on each ſide ſo as to be freely moveable as well towards the Incus as towards the Stapes. This ſame Motion could not have been eaſily obtained in the Articulation of the Incus with the Stapes, without this intervening ſmall Bone.

§. 556. Here again the Stapes and Membrane of the Feneſtra ovalis may be ſtretched or tightned by a wonderful *Artifice*[1], namely, by a Muſcle of the Stapes, which ariſes with a fleſhy Body from a Canal or Groove in the Os petroſum at the bottom of the Tympanum, and then deſcending with a ſmall Tendon, it is connected to the head of the Stapes, ſo that by contracting in an oblique manner, it depreſſes one part and elevates the oppoſite part of that ſmall Membrane.

[1] When the Malleus is drawn inward, and the Membrane of the Tympanum ſtretched, then the Stapes will be moved by the Motion of the Malleus and Incus. But leſt the Stapes ſhould recede from the Feneſtra Ovalis, and impreſs its Tre-

mors upon any part beſides this Membrane of the ſubjacent Feneſtra, therefore the Stapes is provided with a proper Muſcle of its own, which draws that ſmall Bone towards the Os petroſum. And thus the Membrane of the Feneſtra Ovalis is equally ſtretched with the Membrane of the Tympanum; and hence it is that the ſonorous Tremors received by the external Ear, are determined to fall upon a tenſe Membrane the Tympanum, which being put into ſimilar Tremors agitates the Malleus, Incus and Stapes, which communicate the ſame Tremors to the Membrane of the Feneſtra Ovalis, ſo that the number of Vibrations of the internal Air correſpond to thoſe of the external; the interior Membrane being alſo ſtretched in the ſame manner as the Tympanum without.

§. 557. Thus Sounds are conveyed without alteration to this Membrane of the Feneſtra ovalis; but that may by the Apparatus before deſcribed (§. 554, 555, 556.) be ſtretched through an infinite number of degrees of Tenſity, ſo as to be capable of adapting itſelf to receive an infinite number of different Tremors, ſo as to concur harmonically in the like tremulous Vibrations, and communicate the ſame to the cavity of the Labyrinth, for the ſhutting up or incloſing of which, this Membrane of the Feneſtra ovalis is ſubſervient.

§. 558. The large internal *Concha* [1] of an elliptic form communicates with the cellular Cavity of the *Proceſſus Maſtoideus* [2], and with the *Euſtachian Tube* [3] which is partly bony and in part cartilaginous, opening with a

ſmall

ſmall Aperture towards the Palate, which is capable of being ſhut by a cartilaginous ſemilunar Margin, and of communicating with the external Air which is drawn through the Noſe or Mouth. This Tube admits the ſame Air to paſs through into theſe places, where remaining and being rarified, it may afterwards paſs out again and be *renewed* 4, or elſe confined and compreſſed; ſo that, 2. The ſame Air may be reduced to the Denſity of the external Air; and, 3. This Tube ſerves to convey the *ſonorous Rays* 5 admitted by the Noſe or Mouth, that the Perſon might be capable of Hearing, if the Meatus auditorius ſhould by any means be injured or ſtopped up. 4. It ſerves to diſcharge the ſuperfluous Moiſture, which is ſeparated by the *vaſcular* 6 Membrane inveſting theſe Parts, in order to *clean* 7 or render them lax and lubricated.

1 By the internal Concha we underſtand the Cavity of the Tympanum, which is terminated on that Side towards the Meatus Auditorius, by the Membrane which is now abſolutely called the Tympanum, which is convex towards this Cavity, to which the Ancients gave the ſame Name. Oppoſite to the Membrane of the Tympanum is placed the Os petroſum, which is quite rough and perforated with two Openings, the one termed Feneſtra ovalis, oppoſite to the Membrane of the Tympanum, and the other called the Feneſtra rotunda, which lies behind and on one Side of the former. But in the Os petroſum there are ſmall Excavations here and there placed, in which the Muſ-

cles

cles and Veſſels are received. And behind theſe are placed the Cells of the Proceſſus Maſtoideus.

[2] This Proceſs is wanting in Infants, but grows up with Age in proportion to the Head, in the ſame manner as we obſerve the frontal Sinus's abſent in a Fœtus; but which are formed by degrees as the Age advances, when the oppoſite bony Lamellæ recede from their mutual Contacts. Within this Proceſs is contained an infinite Number of bony Lamellæ variouſly connected, and leaving intermediate Vacuities or Cells, each of which being lined with its proper Membrane, is a kind of reſounding Cavity; but all of them communicate with the internal Concha or Cavity of the Tympanum, by which Mechaniſm the Reſonance or Effect of the Sound is greatly increaſed. Thus if the Parchment of a Drum was expanded in the open Air without any reſounding Cavity under it, it would produce an inconſiderable Sound which would ſoon periſh; but when the ſame is extended over a hollow Cylinder, under the Bottom of which is a tenſe Chord, then the ſame Membrane being ſtruck will yield a ſtrong Sound. In our hearing, the Tremors of the Air are conveyed from the external Ear to the Membrane of the Tympanum, which Membrane being ſtruck, communicates the like Tremors to the Air contained in the Cavity of the Tympanum; theſe Tremors fall upon the arched Cell of the maſtoide Proceſs, where they make a great Reſonance. I am indeed not ignorant, that many conſiderable Anatomiſts believe this cellular Proceſs to be of little or no Service towards the Hearing, becauſe they find no Cavity in the ſame in Infants. But for the ſame Reaſon I deduce the contrary Inference, and rather believe it to be the more neceſſary towards the Hearing, which is inconſiderable in the Infant. We know that new born

Infants

Infants are blind, becauſe the aqueous Humour is turbid, which is a great Providence of Nature, leſt coming moſt ſuddenly out of their dark Habitation the Uterus into a ſtrong Light, they might be ſtruck and convulſed by too ſtrong an Impreſſion of the Light upon this tender Organ of Senſe. By the ſame Providence of Nature, they are alſo born in ſome meaſure deaf, the Membrane of the Tympanum being covered over with another mucous Membrane, and the reſounding Meatus Auditorius and Caverns of the maſtoide Proceſs being as yet wanting. But by Age the Organs of Senſe are hardened more to the external Impreſſions of Objects; and therefore by a wiſe Contrivance the Reſonance is increaſed as the Age advances, and as the Nerve becomes leſs tender, leſt our Hearing ſhould deſert us too ſoon.

3 Into the lateral and anterior Part of the Cavity of the Tympanum, opens the Baſis of the hollow and conical Tube of *Euſtachius*, ſo ſhaped that it decreaſes or grows leſs as it paſſes towards the Palate, and at its narroweſt Part is inſerted with its Apex or End into the Cavity of another conical Tube, the Baſis of which is near the Noſe in the Receſs or Cavity belonging to the back Part of the Palate itſelf: for this Tube which is denominated after its Inventor *Euſtachius*, is compoſed of two diſtinct Tubes, the Extremities of which unite together, but their Baſes diverge differently. By this Paſſage the Air drawn in by the Noſe, finds a way into the Cavity of the Tympanum, and gives a free Communication with the external Air, leſt that contained in the Cavity of the Tympanum, being different from that of the Atmoſphere, ſhould be apt to produce Diſcord in receiving and communicating the Vibrations of the latter when the Air is extremely dry, as we now obſerve

obſerve it to a very great Degree [*March* 1727.], ſo as to be uſeful for the Trial of many natural Experiments; in ſuch an Air, the Trumpet ſounds extremely ſharp, whereas in a more moiſt Air, it affords a different and more obtuſe Sound. If therefore the dry external Air ſhould become moiſt without producing the like Alteration in the internal Air of the Ear, we ſhould not hear Sounds as they are in the Air but differently; nor could the internal Air be varied agreeable to the external, unleſs the *Euſtachian* Tube conveyed the external Air into the Cavity of the Tympanum. But the Membrane of the Tympanum propagates the Tremors of the external Air to that which is included, without giving any Admittance to the Air itſelf. The great Neceſſity of theſe Tubes for admitting the Air is evident from Diſeaſes: for *Hippocrates* has left it as an Obſervation, which is alſo confirmed by the Experience of *Valſalva*, that in a Quinſy of the Throat and Fauces, the Patient becomes deaf from a ſhutting up of the *Euſtachian* Tubes, by a ſwelling of the Membranes; and in the Venereal Diſeaſe if any Ulcer ſhould be formed at the Entrance of the *Euſtachian* Tube, the Uſe of that Ear will periſh; and if the like happens to the other Ear, the Patient may bid adieu to his Hearing.

4 The Air which is received into the Cavity of the Tympanum, is there rarified by Warmth, and expands the Membrane of the Tympanum towards the auditory Paſſage, reſiſting at the ſame time the Tremors of the external Air, by which means it would impede the Hearing, if it was not to be changed or renewed at times. The Air is renewed or ſent into this Cavity by the *Euſtachian* Tube, when we breathe with the Mouth very wide open; and hence it is that in gaping we do not hear.

Thoſe

[5] Thoſe who are perfectly deaf from an Obſtruction of the auditory Paſſage, are yet capable of Hearing when the Sound is immediately applied to the *Euſtachian* Tube.

[6] The Malleus, Incus, Stapes, and little Os orbiculare within the Cavity of the Tympanum, together with the Os petroſum, are all inveſted with a vaſcular Perioſteum, the ſmall Arteries of which were firſt demonſtrated by *Ruyſch*; from which Membrane the ſmall Bones of Hearing likewiſe receive thin Ligaments or Capſules inveſting their Articulations, which together with the Membranes ought always to be kept moiſt, that they might not become dry or rigid. The Cavity of the Tympanum therefore ſerves for two Uſes; namely, 1. As a reſounding Cavity to multiply or increaſe the Tremors received from the auditory Paſſage. 2. To ſerve as a vaporous Bath for preſerving the ſmall Bones of Hearing, with their Membranes and Muſcles, moiſt and fit for Motion.

[7] The Tympanum is cleanſed by Sneezing, in which Action the moiſt Sordes of the Ear being ſhook off, are diſcharged through the *Euſtachian* Paſſage; and hence it is that after Sneezing in a Morning, the Hearing becomes more exquiſite.

§. 559. But while the Feneſtra rotunda cloſed with its thin and tenſe Membrane lies open to one Part of the ſpiral Cochlea, and is placed as it were in the Focus of its elliptic Space, oppoſite to the Center of the Membrane of the Tympanum; it is from thence evident, that thoſe ſonorous Rays which act upon this Membrane communicate their Tremors to the ſpiral Cavity of the Cochlea, and make their

Impreſſions

Impreſſions upon the contained Nerve, but perhaps not ſo diſtinctly and accurately as thoſe which are communicated to the Membrane of the Feneſtra ovalis, by means of the Tympanum and ſmall Bones of Hearing.

§. 560. Whether the *Euſtachian* Paſſage is by the Action of the *internal* [1] Muſcle opened at the ſame time, that the Membrane of the Tympanum is drawn towards the ſame, diminiſhing the Cavity of the internal Concha? and whether the Aperture of the ſame Tube near the Palate is *ſhut* [2] with a cartilaginous Valve drawn over by the Contraction of the Cephalo-pharingei Muſcles, preventing any Part of the Aliment from paſſing this way at the time of Deglutition? ſeems more than probable.

[1] *Du Verney* wrote to me, that the ſmall Muſcle of the Malleus aroſe not from the bony but the cartilaginous Part of the *Euſtachian* Tube, which he improperly called the Aqueduct, lined with an Expanſion of tendinous Fibres; thus it happens that by the ſame Action of this Muſcle, the Membrane of the Tympanum is drawn inward and the Tube opened at the ſame time, that the Air which was compreſſed by the Membrane of the Tympanum may paſs from its Cavity into the Fauces. But theſe Opinions of that Anatomiſt are not inſerted in his Works.

[2] If it be aſked, Why the Aliments which we ſwallow do not naturally paſs by this Tube into the Cavity of the Ear, ſince Liquors preſſed endeavour to eſcape every way; we may anſwer, Becauſe the ſame

ſame Muſcles which dilate the Pharynx being ſeated above the *Euſtachian* Tube neceſſarily compreſs the ſame, when they contract and ſwell like other Muſcles. But when theſe Muſcles are deſtroyed by a venereal Ulcer, in that caſe there are ſurpriſing Noiſes and Pains perceived in the Ears at the time of ſwallowing; and even the putrid Aliments have been known to eſcape through the Tympanum, after corroding that Membrane with the ſmall Bones of hearing, ſo as to occaſion a perfect Deafneſs.

§. 561. But ſince alſo the oval Feneſtra or Perforation opens into the hollow *Veſtibulum* [1] which is filled partly with the medullary Portion, partly (1.) of the Nerves which ariſe from the auditory Nerve, and entering through a Foramen in the internal Surface of the Os petroſum, are carried ſtrait forward through ſmall Foramina into the Veſtibulum, where they are diſtributed, defended, and expanded in order through the three ſemicircular bony *Canals* [2], from whence they ſeem to paſs out again in a medulary State. (2.) The medullary Portion of the ſoft auditory Nerve paſſing through the forementioned Foramen into the Apex of the Cochlea through many ſmall Foramina, from whence they are diſtributed in ſlender Filaments through the upper ſpiral Cavity, and from thence again expending a ſoft pulp into the Veſtibulum under the oval Membrane: From all which it is evident that the ſonorous Rays by the trembling of this Membrane are conveyed, by means of theſe agitated

agitated Nerves, to the common Senſory, and there excite the *Idea* 3 of Sound.

Nothing is more ſurpriſing throughout the whole Body than the Fabric of the Os petroſum; it is perhaps above a hundred times harder than any other Bone, even harder than the Teeth themſelves, inſomuch that even in the Fœtus it is almoſt like Marble, when all the other Bones are extremely ſoft; except only that this Bone is alſo ſoft, and almoſt capable of being cut in that part where it unites with the Os ſquamoſum. Into this Bone the Nerve of the ſeventh pair, which the Antients called the fifth, enters; though *Veſalius* neither includes the pathetic Nerve nor the maſtoide Proceſſes; but they are taken in by *Euſtachius* in his Catalogue of the Nerves. This acouſtic Nerve is compoſed of two Trunks, the one ſoft and the other hard, termed the Portio dura and Portio mollis of the auditory Nerve. Theſe two Trunks ariſing from one common origin, paſs together through a large Sinus in that ſide of the Os petroſum which lies towards the Brain; but in this large Sinus, the ſoft Trunk departs from the hard part of the Nerve, which laſt is received into a peculiar Canal, which *Fallopius* has denominated an Aqueduct; which is a very improper name for this Tube, though it is given by one of the firſt Anatomiſts in Europe, *Du Verney*. Through this Aqueduct in the Os petroſum, the Nerve at length paſſes and ſends off the Chorda Tympani, and paſſing on through the maſtoide Proceſs, it goes out by a bony Canal betwixt that and the ſtyloide Proceſs, ſending Branches to thoſe parts of the Head which require to be very ſwiftly moved: Whence it ſeems very probable that theſe Branches are detached from the auditory Nerve, that the

Head

Head might be ſwiftly turned towards any Sound. But the ſoft Portion of the Nerve becomes ſurpriſingly fine in the Bottom of the bony Duct, ſo that it ſeems to vaniſh and terminate in a blind Receſs, like as when the Finger is inſerted to the Bottom of a Glove. But the Induſtry of *Valſalva* has diſcovered five very minute Foramina in the Bottom of this Sinus, which lead into the Os petroſum. Through theſe very minute Canals the Pulp of the Nerve itſelf is conveyed into the Veſtibulum, and there appears to be the immediate and true Inſtrument of the Senſe of Hearing, even though it is by much the ſmalleſt Part in Appearance of the auditory Nerve; for there are only five ſmall Filaments of the auditory Nerve belonging to this Senſe, and deſtined to the Perception of Sounds, all the thick Part of that Nerve being ſpent upon the Integuments.

[2] Of theſe five ſmall Filaments, three of them perforate the Os petroſum, and enter into the three ſemicircular Canals, which are bony, hollow, and reſounding; and in the reſounding Cavities of theſe Canals the three ſmall Nerves are expanded, and at length meet together with the fourth Filament (§. 562.) which entered the Cochlea. But the Veſtibulum is a Cavity in the Os petroſum, which follows next under the Membrane of the Feneſtra ovalis. If it be aſked, Why the three ſemicircular Canals were formed, we anſwer, that the three nervous Filaments might be expanded round them in Order without Confuſion, and defended from the leaſt Injury by ſo firm a Support. But why there ſhould be five Openings to the three Canals, or why Nature has reduced their Number to three, is not our Buſineſs to ſay.

[3] From all that has been ſaid, it is evident that the Membrane of the Tympanum being ſtruck

harmonically by Sounds, transfers the ſame Undulations to the Membrane of the Feneſtra ovalis; under which Membrane follows the ſoft Part of the auditory Nerve, namely, the three Filaments which enter into the ſemicircular Canals, and that fourth Filament which is inflected and ſpread round the other Winding of the Cochlea. Theſe Nerves therefore tremble by the Tremors received from the Membrane of the Feneſtra ovalis ſtruck by the Stapes; and this Tremor in the Nerve is what we call Hearing.

§. 562. But the Fabric of the ſpiral *Cochlea* [1] appears above all to be formed moſt admirably, ſince the Canalis oſſeus, which is conical, makes two ſpiral Turns and a half upwards from its Baſis about its bony Cone, its Apex terminating at the Point of the ſame Cone; and is at the ſame time divided in every Part from the Baſis to the Apex by a triangular Partition which ſevers the ſame into two equal Parts, the Partition itſelf being ſuſtained by the Cone, ſmooth, tremulous, and elaſtic; on the outward Part which reſpects the Cone that ſupports the ſame, it is a nervous Membrane in ſome meaſure attached to the forementioned bony Parts and partly fixed to the Canalis oſſeus; ſo that thus theſe two ſpiral Cavities do not at all communicate, but the Mouth of the uppermoſt opens into the Veſtibulum, and the lowermoſt is cloſed by the Membrane of the Feneſtra rotunda; and thus the very tender ſmall acouſtic *Nerves* [2], appear to be every where diſtributed throughout.

By

[1] By the Cochlea we underſtand a ſpiral Body, which is hollow and of a conical Figure, partitioned into two ſemi-conical Cavities. The Septum, which divides the hollow Cone into two Cavities, is a triangular Iſoſeles; and that Portion of it which belongs to each Cavity, is a right-angled Triangle. For when a ſtrait Cone is divided perpendicularly to its Baſis, the Plane which paſſes through its Center will divide the Cone into two equicrural Triangles, and if the ſame be divided through its Axis, it will form two equal and right-angled Triangles. Now one of the right-angled Triangles in the Cochlea is bony, and the other membranous or nervous. But again, this whole equicrural Triangle, with the two right Angles of which it is compoſed, is inflected in the Cochlea round a Cone, ſo as to deſcribe the Spiral of *Archimedes*; namely, two whole Circumvolutions and a half. This Fabric was choſe by Nature for reducing the ſame into a ſmall compaſs; for a Spiral is ſix times longer than the right Line about which it is inflected.

[2] The two Cavities of the Cochlea have each their particular Nerve, which is inflected round their hollow Surface. But there is alſo another ſmall Filament, which is one of the five Nerves before-mentioned, (§. 561.) which is ſent into the winding of the Veſtibulum which terminates under the Feneſtra ovalis; and therefore this laſt ſmall Nerve is expoſed to the Tremors of the Membrane belonging to the Feneſtra ovalis, which receives its Vibrations from thoſe of the Air conveyed through the external Ear to the Tympanum. But the other ſmall Nerve which enters through the Apex of the Cochlea, and is ſpread through the ſecond Cavity thereof; namely, the winding of the Tympanum inflected or circumvoluted into

two rounds and a half; and this laſt Cavity terminates at the Feneſtra rotunda, in which there is nothing either of Muſcle or Bone, but only a thin tremulous Membrane. Theſe two laſt mentioned Scales or winding Stairs are of great uſe. When we do not attend to Sound, the Membrane of the Tympanum is ſtretched to ſome particular Degree of Tenſion, and in that caſe a Man who is in Silence and Meditation will diſtinctly perceive only one Sound, namely, that which is in uniſon with the Tenſion of the Membrane of the Tympanum: but in talking, the other Sound which was indiſtinctly received eſcapes the Perſon, who looking round ſays to his Friend, I heard you ſay ſomething but it eſcaped me. This firſt confuſed Perception, which is conveyed to the common Senſory, ſeems to ariſe through the Feneſtra rotunda, which is a ſimple Membrane, immutable, and furniſhed with no Machine to vary its Tenſion; whence it ſeems to be the true Organ of indiſtinct Hearing, which we commonly call a Noiſe: But when the Mind thus perceives any ſuch indiſtinct Sound, the Ears are immediately erected, that is to ſay, the Tympanum is ſtretched by the Contraction of the three Muſcles which belong to the Malleus and Stapes; which Tenſion is gradually increaſed till it finds the ſingle Point or Degree which is harmonical with the external Sound, and then the Hearing is diſtinct. Hence therefore the Organ of Hearing ſeems to be twofold, one for admoniſhing and giving warning, and the other for diſtinguiſhing.

§. 563. For by this *Contrivance* it is poſſible for an infinite Number of ſmall tremulous Chords to be aſſigned, of an equal Degree of Tenſity in this Lamella, in a Direction from its

its Baſis terminating in its Apex; ſo that among theſe almoſt innumerable Chords there will be always ſome, which being in harmonical Conſent, will tremble with every Sound, ſo as to be capable of repreſenting the ſame, and of conveying it as ſuch to the common Senſory; ſo that the nice Diſtinction of different Sounds is performed by means of the Membrane belonging to the Feneſtra ovalis, while the Office of the Membrane of the Feneſtra rotunda is only to give notice of a Noiſe or indiſtinct Sound, the Perception of which being communicated excites the Attention, by which means at the ſame time the bony *Organs*[2] of Hearing and the Tympanum are ſtretched by their reſpective Muſcles, that they may be capable of diſtinguiſhing what is heard.

[1] They who are verſed in the Principles of Geometry will eaſily underſtand what is here ſaid. Let us ſuppoſe a Circle, in the Center of which is erected a right Line perpendicular to the Plane of the Circle of any given Height; and from the Point or Top of that Line, let a tangent Line be drawn to any Point of the Circumference of the Circle: If this Tangent be moved round the whole Circumference of the Circle, while it remains fixed to the Apex or Top of the perpendicular Line, it will produce or generate a true Cone. From the Apex of ſuch a Cone, let two right Lines be drawn to the two extreme Points of any of its Diameters; and thus will be formed by theſe Lines an Iſoſeles Triangle, which will divide the Cone into two equal Parts. But this Triangle will

be divided by that perpendicular Line which we call the Axis of the Cone, into two right-angled Triangles. If now an infinite Number of Lines, parallel to the Baſis of the Circle, are drawn from that Axis to either Side of the Triangle, all of them together with the Axis and thoſe Sides will form Triangles which will intercept ſimilar Triangles, and will be conſtantly the ſame as to their Angles, in which the parallel Lines interſect the Sides of the largeſt Triangle, the Apex of which will conſtantly remain the ſame. All poſſible Lengths therefore may be formed betwixt the largeſt and the leaſt in theſe Lines parallel to the Baſis, even from the greateſt (namely, the Radius of the Baſis of the Cone) to the ſmalleſt, which is but little differing from a Point infinitely minute. What has been before advanced is applicable to the Cochlea, the Septum, or Partition of which (§. 562.) is ſuch a right-angled Triangle; and the ſmall Nerves deſcending from the Center of the the Nucleus or Axis to the Circumference of the ſpiral Lamina, will be thoſe parallel Lines of which we before ſpoke. It therefore only remains for an infinite Number of nervous Chords of all Lengths to be formed betwixt the Point or Apex and Semi-diameter of the ſpiral Lamina of the Cochlea, where it is broadeſt at its Baſis. But thus we ſhall have an infinite Number of Chords, which may tremble in uniſon with the infinite Variety of Sounds; the longeſt of them will expreſs the moſt grave Tones, and the ſhorteſt the moſt acute Tones: ſo that among the infinite Variety, if one Chord will not tremble at a particular Sound, yet another will be found to tremble, harmonically; but when that Chord trembles all the reſt which are octaves, fifths, or thirds, greater or leſs, will alſo conjoin their Tremors to form one harmonical Sound;

Sound; and thus it will be conveyed to the auditory Nerve, which communicating the ſame to the Brain produces the Senſe of Hearing. From hence therefore the Reaſon is evident why we are capable of ſuch an exquiſite Diſtinction of Sounds, and alſo why we do not perceive the greateſt Sounds nor the leaſt by the Senſe of Hearing; namely, becauſe neither of them can find a conſonant Chord in the ſpiral Lamina of the Cochlea. Thus the largeſt Pipe in the Organ being blown, yields a Tone hardly perceptible to the Ears. And from hence again it is evident, why half of the Septum of the Cochlea is bony; namely, that the Chords thereto attached might reſound; for if muſical Chords are faſtened to a ſoft Body, they never yield any Tone.

[a] The Organ of Hearing is the moſt complex of any belonging to the Senſes, for it includes, (1.) The external Ear with its Excavations, Eminences, Muſcles, *&c.* (2.) The Meatus Auditorius with its anterior, cartilaginous and poſterior bony Part lined with its proper Membrane. (3.) The threefold Membrane of the Tympanum, with the tremulous Chord ſtretched underneath, which is elaſtic and nervous, compoſed of two different Trunks of Nerves like unto the Chords which are ſtretched under the Parchment of ordinary Drums. (4.) The four ſmall Bones of Hearing, with their four Muſcles and Ligaments. (5.) The Cavity of the Tympanum, with its appendage in the maſtoide Proceſs. (6.) The *Euſtachian* Tube, with its dilating Muſcles and double cartilaginous Gate or Entrance which opens near the Noſe. (7.) The Os petroſum, with the Aqueduct of *Fallopius* and hard part of the Nerve. (8.) The ſoft auditory Nerve dividing itſelf into five Branches of ſmall Nerves, two of which are ſpread

round as many ſpiral Cavities in the Tympanum, and three are ſpread within the ſemicircular Canals. Four of theſe Nerves terminate at the Feneſtra ovalis, and one of them at the Feneſtra rotunda. (9.) The Feneſtra ovalis and rotunda, with the Veſtibulum, Cochlea, and ſemicircular Canals. With ſuch a wonderful and complex Fabric has Nature formed this Organ, not only to be ſenſible of any one ſingle Sound, but alſo that we might perceive all Tones which are Harmonical; and therefore it was neceſſary for the Ear to be a perfect muſical Inſtrument or Organ; and hence it was neceſſary for it to be provided with ſo many ſmall Bones and Muſcles, *&c.* But this Multiplicity of Parts in the Organ of Hearing, renders it difficult for the Phyſician to determine from what Cauſe Deafneſs ariſes; for the Parts are very numerous, and may be injured various ways. The external auditory Paſſage may be obſtructed, the Membrane of the Tympanum may oſſify or become callous, or it may be broke, the Perioſtea of the ſmall Bones may cauſe them to grow together, the ſame Bones may be corrupted, the Membrane of the Feneſtra rotunda or ovalis may become Callous, the *Euſtachian* Tube may be ſtopped up; and, laſtly, in the ſingle Labyrinth may happen a thouſand Diſorders which may deſtroy the Hearing.

§. 564. But whether or no the extreme Filaments of theſe ſmall Nerves having performed their Office, and been diſtributed within the Labyrinth, *return* again to the Brain and common Senſory, is much to be queſtioned? But thus *Simoncelli* has thought, and ſo it has been repreſented by *Miſtichelli* in his

his Letters. In ſhort, an infinite Number of Enquiries remain ſtill to be made.

These minute Anatomiſts propoſed a new Diſcovery with which at firſt I was wonderfully taken. They affirmed that the ſoft and hard part of the auditory Nerve indeed enter'd the auditory Sinus, and were there expanded ſeparately in the manner which is commonly known; but then, ſay they, the ſoft Nerve does not there terminate as is commonly ſuppoſed, but returns again to the Brain into which it penetrates very deeply: and therefore is not Hearing performed in the auditory Nerve when it is returned into the Brain, and not in the Os petroſum? To this they add, a very conſiderable Conjecture, namely, that the Senſes return to the Brain, by the Communications of the Nerves. But theſe Anatomiſts ſeem to have indulged Conjecture too much, going beyond the Limits of Experience; for no one could ever repeat their Diſcoveries, which never appeared to me upon the moſt diligent Enquiry, and which were not ſupported even by the Diſcoverer in his latter Epiſtles. They might have been impoſed upon by that ſmall branch of a Nerve which comes from the Organ of Hearing, and paſſes into the Dura Mater of the Brain; which Communication betwixt the Nerves ought not to ſeem ſurpriſing, ſince the internal Perioſteum of the Os petroſum is a ſingle Membrane continuous with the Dura Mater. But then it ought not from thence to be aſſerted, that the ſoft Nerve returns to the Brain after it has enterd the Veſtibulum in the form of a Pulp; for this ſeems to be repugnant both to Reaſon and Experience. The Heart propels the Blood into the Brain with a conſiderable Force, and diſtends the ſame as it were on all ſides in Lines drawn

drawn from a Center to the Circumference; and therefore for any Humour to return into the Brain, it muſt be propelled with a Force capable of overcoming the Reſiſtance of the Blood ſent to the Brain from the Heart; but ſuch a Force can by no means be ſuppoſed in a ſoft Nerve, which is not only a moſt ſoft Pulp, but is likewiſe not provided with any muſcular Power in the Ear, whereby any ſuch Force can be communicated.

§. 565. From hence we may be capable of underſtanding the reaſon why the Hearing is more acute or quick by applying the Hand *hollow* [1] to the external Ear, and directing the ſame towards the ſonorous Rays?

Why, on the contrary, the Hearing is difficult or more dull when the *external Ear* [2] is cut off?

Why the Hearing is more exquiſite when the Plane of the Ear is directed towards the Sound at an *Obliquity* [3] of forty-five Degrees?

And why we hear more plainly when the Mouth is open and the lower Jaw hangs *pendulous* [4]?

Why there is a humming Noiſe in the Ear, ſo as to render the Hearing more dull when we *whiſtle* [5] or blow, gape, blow the Noſe, ſpeak *ſhrill* [6] or *ſing* [7]?

Why deaf People hear the *gnaſhing* [8] of their Teeth, or the Sound of a Body which is held betwixt them?

And why deaf People likewiſe frequently hear well by ſpeaking into their *Mouth* [9]?

Why

Why Deafneſs follows from any kind of Obſtruction in the Cavity of the *Euſtachian Tube* [10]?

Why Deafneſs likewiſe follows from a *Rupture* [11] of the Membrane of the Tympanum?

By what Paſſage ſome People are capable of diſcharging *Smoak* [12] from their Mouth through their Ears?

Whence it is that we hear but *one* [13] diſtinct Sound not at all confuſed, though received by two different Ears.

[1] Children in Churches endeavour to move ſurpriſe in their Companions, by directing them to apply their hollow Hand to the external Ear, by which means the Sound is conveyed three times ſtronger than if it was received by the external Auricle only; for the Hand thus receives the Tremors of the Air in the ſame manner as the external Ear itſelf, but in twice as great a quantity, as it is twice as broad.

[2] This happens when the external Ear is loſt even in Men who before heard the moſt exquiſitely. For when the external Ear is loſt, all thoſe ſonorous Rays ſlip on one ſide which do not enter the Ear in a right Line from the ſonorous Body. But the Surface receiving the ſonorous Rays being diminiſhed, and part of the reflecting Machine being deſtroyed, the number of ſonorous Rays muſt conſequently be leſſened ſo as to conſiderably weaken the Sound. For the external Ear, as we obſerved before, ſtands out at a diſtance from the Sphere of the Head, and collects together the Rays which would otherwiſe have eſcaped; and therefore People who are deprived of this collecting Machine muſt be obliged to direct their Ears towards

towards every Sound, like Horſes and Dogs who have had their Ears cut off, by which means hardly one tenth part of the Hearing remains; ſo that in theſe Animals we may perceive that they move their Head continually towards all quarters to receive the ſonorous Rays, as if they were ſenſible of their loſs of this collecting Machine.

[3] Hence it is that People who are deaf do not turn their Face towards the Preacher like other People, but the ſide of their Head inclined a little obliquely; for when they look directly towards the Speaker, the convex Face of the Ear being turned towards the ſonorous Object, admits much fewer Rays than if they were to be received and collected by the broad and hollow part of the Ear directed oppoſite to the Perſon ſpeaking.

[4] When a Perſon is in ſome Solitude, and perceives a Sound coming from a Diſtance, which he deſires to perceive more diſtinctly; if we then obſerve the endeavours uſed to hear attentively, we ſhall find that he ſtands quite ſtill, holds his Breath and opens his Mouth, becauſe then the Sound penetrates the arched part of the Palate and *Euſtachian* Tube to the internal Ear, almoſt in as great a quantity as through the Meatus Auditorius, by which there is almoſt double the quantity of ſonorous Rays collected. When ſkilful Painters draw *Apollo* ſtriking the Harp, they expreſs the People Hearing with the greateſt attention of Mind with their Mouths drawn wide open. They might poſſibly have taken this from having obſerved the common People giving audience to a Mountebank, who being full of Credulity ſtand gaping and with erected Ears to receive what he has to ſay.

[5] We are ſaid to blow when we draw in a large Quantity of Air by Inſpiration, and retaining the ſame for a while, and cloſing the Cavity of the Noſtrils

Noſtrils by the Velum of the Palate as with a Curtain, we then expel all the Air through the Mouth contracted into a narrow Opening, increaſing the Celerity of the Air's Current by diminiſhing the Aperture of the Tube. In this Action therefore the Air being collected and retained, ruſhes towards the Mouth; and not finding there an eaſy Paſſage, enters the *Euſtachian* Tube and internal Ear, ſo as to preſs outward the Membrane of the Tympanum, reſiſt Sounds coming through the Meatus auditorius, and occaſion us to hear an indiſtinct buzzing Noiſe inſtead of a clear Voice.

[6] A Perſon who is uſed to ſpeak with a grave Voice, endeavours to ſpeak with an acute Tone in order to be heard at a greater Diſtance, the Tone being then feminine and ſharp; and thoſe who thus uſe a maſculine and ſtrong Voice, when they endeavour to ſpeak with ſuch a ſhrill and puerile Voice, they do it with ſome Difficulty of ſtraining. This Shrilneſs of Voice is formed by a very cloſe Approximation of the Glottis, through which the Air is very ſwiftly propelled from the Thorax; and by the ſame means likewiſe the Air ruſhes through the *Euſtachian* Tube into the internal Ear. *Tiberius Gracchus*, who was one of the greateſt Orators of his Age, when ſpeaking with the greateſt Intenſity of Mind to the People, uſed to cry out like an old Woman, nor did he himſelf hear in what a diſagreeable Manner he ſpoke; but to avoid this, he had a Servant who uſed to ſound a Pipe of an acute Tone, to which he rendered his Voice conformable.

[7] When Perſons who are very well ſkill'd in Muſic, are deſired to ſing to any muſical Inſtrument higher, or in a more acute Strain than is natural to their Voice, they eaſily err when they come to the moſt acute Tones, nor can they expreſs

preſs by their greateſt Endeavours thoſe Tones which have been ſet before them by the Organ; and therefore the Ears are diſagreeably affected whenever the Voice is ſtrain'd in that manner: for in the moſt acute Tones the Glottis is very ſtrictly approximated together, and the Air is very ſwiftly expelled, both which are Cauſes of a ſhrill Voice: but the Air ruſhing with great Rapidity through the Glottis, enters the *Euſtachian* Tube of the internal Ear, ſo as to diſturb the Perception of the external Sound.

[8] Deaf People who can hear nothing with their Ears, may yet hear by their Mouth. Let a deaf Perſon hold an iron Rod betwixt his Teeth pendulous, and then upon ſtriking the ſame he will perceive the Sound of the trembling Iron. There was a certain Muſician at a Court, who became deaf by Diſeaſe; but by holding the Handle of the Lute in his Mouth, he could then ſtrike the ſame agreeable to the Rules of Art. It is to be obſerved, that the Tremors of the Air are like the Returns of elaſtic or reſalient Bodies; but an iron Rod being ſtruck, trembles and communicates its Tremors to the Teeth, ſo as to ſhake all the Bones of the Head, and with them likewiſe the auditory Nerve, as if it was affected by the Tremors of the Air conveyed to the Tympanum. Deaf People are capable of hearing the Diſcourſe of others, while they are carried over the Stones in Coaches or Waggons which have iron Chains making a rattling Noiſe; whereas they hear nothing when the Carriage ſtands ſtill. The Daughter of the great *Colaart* was deaf from her Birth; but yet ſhe could hear and underſtand, when the whole Houſe was ſhook by the Report of a Gun. This Virgin was taught to ſpeak by *Ammanus*, and anſwered to thoſe who aſked her, that when ſhe

ſpoke

ſpoke ſhe perceived ſomething, but could not tell whether that Senſe was the ſame with what we call Hearing. She certainly heard internally, but could not uſe the Term Hearing in that Senſe in which we underſtand it, ſince ſhe never heard in that manner: for they who have never heard are ignorant of what Hearing is, and conſequently they are not able to explain that by Words which they know nothing of. But when the *Euſtachian* Tube is alſo obſtructed, in that Caſe deaf People are not able to hear the ſtrongeſt Sounds.

[9] I ſaw a Perſon who having loſt the external Ear, uſed to receive Sounds by his Mouth; and there are many Inſtances of this when the auditory Paſſage is ſtopped up, or the Membrane of the Tympanum render'd callous; for Sounds coming through the Mouth, are impelled upon the arched Roof of the Palate, and are from thence reflected to the internal Ear through the *Euſtachian* Tube.

[10] Upon this I have made ſome Obſervations. A venereal Ulcer being ſeated near theſe Parts, or Aphthæ being ſpread round the Fauces occaſion Deafneſs, but not ſuch as is incurable when the Ulcer or Aphthæ are removed. When the *Euſtachian* Tube is ſhut up, the Air retained in the Tympanum, without finding any Vent, is in the mean time heated and rarified ſo as to thruſt the Membrane of the Tympanum outwards, and preſs the Membrane of the Feneſtra ovalis inwards, by which means the Communication of the Tremors of the external Air to the auditory Nerve is interrupted. This kind of Deafneſs frequently happens from Quinſeys, when there is a Metaſtaſis or Tranſlation of the morbific Matter in a Pleuriſy upon theſe Parts; for Matter or Mucus compreſſes the *Euſtachian* Paſſage; and hence this kind of Deafneſs is cured by a Diarrhæa following, by tranſla-

ting the Matter another way as *Hippocrates* has obſerved of old.

[11] The *Italian* Philoſophers have made many Experiments in this reſpect by breaking the Membrane of the Tympanum in living Dogs, by which means the Hearing continued for ſome time, but gradually leſſened, till at length the Animal became quite deaf. For when the Membrane is firſt deſtroyed, the Malleus, Incus and Stapes do nevertheleſs remain in their proper Situations, and are capable of transferring their Tremors to the Feneſtra ovalis. But afterwards by degrees the ſmall Bones with their Membranes and Ligaments are dried up by the external Air, contract and become rigid, while the Tympanum is filled with Duſt and other ſmall Bodies floating in the Air, which totally deſtroys the Hearing. Such an Accident I knew in a certain great Prince who ſtood too near a very great Gun at the Time when it was diſcharged. But ſometimes the Hearing does not totally periſh when this Membrane is wounded; for the Membrane of the Tympanum may be eaſily renewed, and the Wound of it healed, provided the Ears are continually defended from the Injuries of the Air.

[12] If a deaf Patient comes to conſult you concerning his Hearing, order him to retain the Air, and make the ſame endeavour as if it was to be blown through the Mouth and Noſe which are at the ſame time ſhut: If now the Air is blown thro' the Ear, the Diſorder is incurable. For the Membrane of the Tympanum ſometimes departs from the bony Circle, but this not without Diſeaſe, ſince it naturally adheres very firm. In a Patient who is thus afflicted, the Smoak of Tobacco being received into the Mouth after the Noſtrils are cloſed, it may be blown together with the Air through

through the *Euſtachian* Tube, ſo as to paſs out through the external Ear. But in the wild Goat this Fabric or departing of the Membrane of the Tympanum from the bony Ring ſeems to be natural; ſince they are not ſuffocated by ſtopping their Mouth and Noſe, but live by the Air drawn through their Ears. This we are told by *Ariſtotle*.

[13] This Queſtion is not eaſy to ſolve, nor is it anſwered by *Valſalva* by ſaying that the ſemicircular Canals are of the ſame Length both in the right and left Ear of the ſame Perſon; for who can ſo much as hope to take an accurate Dimenſion of theſe Cavities, ſeeing the Difference of a Grain of Sand in their Length will here make a conſiderable Variation. But this Queſtion ſeems to be the ſame with that which we propoſed with regard to the Eyes; namely, why we ſee but one Image with two Eyes, when at the ſame time the Image of the Object is painted both in the right and in the left Eye, and by them tranſmitted to the Mind. But this Phænomenon ſeems to be explicable in the following manner. So long as the Muſcles of the Malleus and Stapes continue perfectly in the ſame Degree of Tenſion in each Ear, we then hear but one Sound, both the right and left Ear being then in Uniſon or Conſonance. But even at other times when I perſuade myſelf that I hear but one Sound, I then hear perhaps a thouſand collected into one; for the infinite Number of Bodies which are in harmonical Conſent tremble together at every Sound, which is thus increaſed by new Vibrations, all running together into one whole Tone. When a thouſand People ſing in a Church, while at the ſame time the Organ plays, there are then a great many different Tones produced at the ſame time; perhaps there may be eight Tones in the Organ and four among the People; for ſome Men ſing

Baſe, others Tenor, and others Treble; but the Women ſing in Alt. But if now there is only one Perſon among them all unſkilled in Harmony, I then hear all the reſt as one Tone, and diſtinguiſh the Voice of that one Perſon as a different and diſcording Sound. Thus alſo there are ſome People who ſuffer an almoſt intolerable tingling in their Ears from their own Voice, inſomuch that they are obliged to ſtop their Ears till the Force of the Diſorder is over. Theſe People ſeem to have loſt the Conſonance, which is neceſſary in the Organs of Hearing, which cannot all be ſtretched to Uniſon; otherwiſe this Phænomenon ſeems to be unexplicable. Concerning Sounds and Harmony *Merſennus* has wrote the beſt in his very ſcarce Book, entitled, *Harmonicorum, lib.* 12. *Fol.* 1648; as alſo in another Volume of Commentaries upon the Book of *Geneſis*, in which many different philoſophical Experiments are contained; for that Perſon being a Divine, endeavoured as much as poſſible to refer his Writings under ſacred Titles. *Kircher* has alſo publiſhed two Books in Folio upon Harmony, the one is *Muſurgia Univerſalis*, printed at *Rome, ann.* 1650; and the other entitled *Phonurgia*, being a Compendium of the former, *ann.* 1670.

Of the Internal Senſes.

§. 566. FROM all that has been hitherto ſaid (§. 481 to 566.), we learn that our Bodies receive nothing elſe from ſenſible Objects to produce Senſation, than a *Change in the Surface* [1] of the Nerve, excited by the Contact of the moving Object.

Seeing

[1] Seeing is the Retina or pulpy Expanſion of the optic Nerve touched by a Focus of the Rays of Light. Smelling is the Feeling or Contact of odorous Particles with the Surface of the olfactory Nerve expanded upon the Bones of the internal Noſe. Taſting is alſo that kind of feeling, which is produced from the Contact of ſapid Bodies with the Papillæ of the Tongue, ariſing from the Branches of the ninth Pair of Nerves; and the Touch or Feeling is a Motion excited in the ſoft ſubcutaneous Papillæ by ſome Body rubbing againſt the Cuticle. And laſtly, Hearing is performed when a ſonorous Wave or Undulation of the Air makes an Impreſſion upon the auditory Nerve by exciting harmonical Tremors in the Membrane of the Feneſtra ovalis. We never hear without Sound, nor ſee without Light, nor do we even perceive but by ſome Alteration made in the Body and Organ of Senſe. But in the ſenſitive Organ itſelf, there is no other Change but that received by the Nerve of each Organ; for Nature has ſo defended the Nerves in every Part, that it is impoſſible for the Body which is perceived to penetrate into the perceiving Nerve, or to make any Alteration in the ſame, but what is received in its Surface. When therefore the Mind perceives any Change in its Ideas or Thoughts, the Body is changed in ſome of its ſenſitive Organs; and that Change is made in the Surface of the Nerve belonging to each Organ. So great is the Simplicity of this Contrivance, that it is with Difficulty we can confide in the Truth of it; but this is rather an Argument of its being the Work of infinite Wiſdom, which is capable of producing the moſt complex and intricate Effects by the moſt ſimple Means. I do not ſay that this Change in

the Nerve is Perception, but I ſay that we perceive when ſuch a Change is made.

§. 567. This Change in the Surface of the Nerve is produced by the various *Figure* [1] and Bulk, Hardneſs and Motion of the ſenſible Object: whence it ſeems probable that ſenſible Bodies, however different, would always excite the ſame Senſe upon the ſame Organ, provided they were exactly the ſame in theſe four *Qualities* [2].

[1] If a Dram of Gold is beaten into thin Leaves by the Hammer, there will be nothing in it capable of affecting the Taſte, Smelling, or Hearing; but if the ſame Gold is formed into a ſharp-pointed Bodkin, it will wound the Tongue, and excite Pain; or if it is formed into a Bell, it will produce Sound, and affect the Ear, *&c.* and therefore only by changing the Figure of a Body, which is in its own Nature moſt ſimple, its Action or Efficacy may be varied ſeveral Ways.

[2] That is to ſay, with reſpect to their Denſity, Rarity, Magnitude and Minuteneſs, Hardneſs and Motion. For theſe Qualities being changed, the Nature of the Body is alſo changed with reſpect to us, ſo as to make the Body ſeem to be of another kind. Every ſenſible Object which agrees with ſome other in Figure, Bulk, Hardneſs and Motion, will excite the ſame Senſation, and will be taken for the ſame Body. Gold broke into the moſt minute Particles, and applied to the Tongue, does not excite any manner of Taſte; but if the ſame is diſſolved in Spirit of Sea Salt, or in Aqua regia, till the Menſtruum is ſaturated, it will continually excite a ſweetiſh and aſtringent Taſte.

The

The Elements or Particles of pure Gold do not excite any manner of Taſte; but Aqua regia, though not more in proportion than the thouſandth Part in a drop of common Water, will excite the Taſte of a ſtrong Acid. But a Solution of Gold in ſuch a Menſtruum has neither the Inſipidity of that Metal, nor yet the Acidity of the Aqua regia, but a new and peculiar kind of aſtringent Taſte. If now a Particle of Silver equally ſmall with a Particle of Gold can be endowed with the ſame Weight and Denſity, Hardneſs and Figure with that of the Particle of Gold, it would certainly be no longer Silver but Gold; ſince there would be no Difference, but the ſame Particle of Silver being diſſolved in Aqua regia would afford the ſame ſweetiſh and aſtringent Taſte with Gold. If I can communicate the ſame Motion, Figure, Hardneſs and Denſity to any ſmall Body which is peculiar to Fire, there is no room to doubt but that Particle or Body will become actual Fire. But it is not in our Power by any Artifice in Chemiſtry ſo to change a Body, as to render it capable of pervading Glaſs without altering its Powers; and in general, if all Bodies in the Univerſe had the ſame Denſity, Figure, Hardneſs and Magnitude, they would always communicate the ſame Senſe or Impreſſion to our Organs; for though they might differ with reſpect to each other, yet with regard to us they would not be different. Nor is there any other way by which we can diſtinguiſh Bodies, but by theſe four Qualities which we perceive by our Senſes. Aſk one of the more modern Philoſophers, who neglect this Simplicity, what Gold is; and he will anſwer, that it is a Metal the moſt ponderous, the moſt ductile, of a determinate Colour, *&c.* which are truly the characteriſtic Marks by which we diſtinguiſh Gold

from all other Bodies. But then it is to be obſerved, that all theſe Marks belong to the four Heads before-mentioned; for the Weight is diſcovered by the Balance, *&c.*

§. 568. But this Change only in the Nerve is not ſufficient to produce Senſation; but it is farther required, that the ſame Change be *propagated* [1] through a free Nerve to ſome Part in the Medulla of the Brain, and from every *ſingle* [2] Nerve to a correſponding particular Part in the Medulla of the Brain; and this we learn from Ligatures, Wounds, and Corruptions of the *Nerves* [3] and Brain.

[1] It muſt indeed be owned, that the celebrated Naturaliſt *Perrault* is of another Opinion; but certain it is, that when the Brain only is at reſt in Sleep no Senſe ariſes, even though the ſame Impreſſion be made upon the ſenſitive Organ: and therefore a mere Change in the Surface of the Nerve of the ſenſitive Organ is not alone ſufficient to excite Ideas in the Mind; but it is neceſſary for the Effect of this Change on the Nerve (I will not ſay the Change itſelf) to be propagated into the Brain, ſo as to produce a like Change in that Part of the Brain where the Nerve terminates, and which receives the Impreſſion. When two Ounces of Water are extravaſated into the Ventricles of the Brain, the Patient is not ſenſible of any thing, not ſo much even as the Report of the largeſt Gun nor the ſtrongeſt Light, nor yet even the moſt exquiſite Pain of burning. Hitherto belongs that wonderful Hiſtory of the Woman at *Paris* (§. 284.) who having loſt Part of her Scull went about aſking Alms with her Brain only covered

vered with ſoft Integuments. Such a Woman I alſo ſaw dwelling in the Village of *Alphen*, in other reſpects well, only having loſt a great Part of the Os bregmatis.

[2] The Effect of this Change or Impreſſion upon each Nerve is tranſmitted from thence into correſponding particular Parts of the Medulla of the Brain. If I touch my naked Body with the Fore-finger, there follows a Senſation; and if I touch the ſame Body with the Fore-finger of the left Hand whilſt contained in a Glove, there then ariſes two very diſtinct Senſations at one and the ſame time in my Mind; and therefore it follows, that the Effect of the Impreſſion or Change which ariſes from the Touch of the right Fore-finger, does not extend to the ſame Part in the Brain where the Effect of the Change terminates, which aroſe from the Touch of the left Fore-finger; for if both theſe Changes were conveyed to one and the ſame place, they could not by any means excite diſtinct Senſations in the Mind, but they would be confuſed together as one. One who duly conſiders all theſe Particulars will eaſily perceive that there muſt be as many diſtinct Parts in the Medulla of the Brain, as there are different Senſes ariſing from different Nerves formed into diſtinct Organs for Senſation; but all theſe Parts together in the Medulla of the Brain form the common Senſory: for thus do we call that Part in which all the Nerves terminate, and to which they convey the ſeveral Changes impreſſed upon the ſenſitive Organs. But all the Nerves ariſe from the Brain, and therefore the common Senſory muſt be ſeated in the Brain.

[3] If it be aſked, What Change is made in the ſentient Nerve; I anſwer, that the Spirits propel forward thoſe which lie next adjacent; and theſe

again move the next, till the laſt but one moves the very laſt; and therefore the Change in the common Senſory can be nothing more than a Repulſe of the Spirits againſt their Origin. This is certainly a very ſimple Explanation, but we know not of any other.

§. 569. But this Change received in the common Senſory is there ſo ſmall and ſo *ſimple* [1], that nothing can be more ſo, and therefore by reaſon of that Simplicity can hardly be traced or explained.

[1] When the Pulp of the optic Nerve receives the Image of an Object, the Mind perceives or ſees, and at the ſame time diſtinguiſhes the Eyes, Noſe, Hair, and other Parts of the perceived Image. But what is it that then happens in the Eye? This we are beſt able to learn by Experiment. If the Bulb of the Eye be taken out of the Orbit without injuring any of its Parts; and if then Part of the Sclerotica be cut off with a moſt ſharp Scalpel from the Back-part of the Globe, removing afterwards the Tunica Choroides and *Ruyſchiana*, there then remains the naked optic Nerve expanded into a white pellucid Mucus, which we call the Retina. To this Retina, inſtead of the Choroides and Sclerotica which have been removed, let a piece of Paper be applied, whoſe Concavity correſponds to the Convexity of the Eye, and you will then ſee the Image of that Object painted upon the Paper juſt as it is before the Cornea; and therefore the optic Nerve in the Act of Viſion receives the painted Image of the viſible Object. This Image is a proportionable Diminution and Repreſentation of the Rays coming

coming from an Object in the ſame Order which they came to the Object. But then how ſubtle is the Impreſſion of this Image! The Rays of the full Moon collected and thrown upon a Paper by a Convex-glaſs, make a white luminous Spot in their Focus which is intolerable to the Eye, and yet does not the moſt ſenſible Thermometer demonſtrate the leaſt Degree of Heat in that Focus greater than the Heat of the nocturnal Air (§.541.) Again, there is ſomething conveyed through the optic Nerve to the Thalami or Chambers from whence they ariſe; but that which is conveyed through them, is not the Image which was painted upon the Retina. But if we conceive as many ſmall Fibres in the optic Nerve, as there are minute Points in the Image of the Object painted upon the Retina, it will be evident that nothing more can happen, than that each Fibril muſt receive ſome Point of the Image, that is to ſay, will ſuffer ſome Change in its Surface. But this Change in a ſingle Point cannot but be the moſt ſimple, nor can it produce any thing more in the common Senſory than the ſlighteſt Change, or an infinitely ſmall Tremor or Shock. It is a well known Experiment, that if one of the tall Firs uſed for the Maſts of Ships, growing ſometimes to the Height of 130 Feet in the Mountains of *Helvetia*, lies down upon the Ground, by applying one Ear to the Extremity of this long Tree, if you then order a Friend to ſcratch very gently with his Nail at the other End, you will plainly perceive the Noiſe, though it cannot be diſcerned by thoſe who ſtand nearer to its Origin. Thus you ſee how ſmall a Motion may be propagated to ſo great a Diſtance through ſo hard a Body, which might well appear incredible to a Perſon who has not experienced the ſame. But we are

ſtill

ſtill taught ſomething more ſurpriſing by *Huygens*. Let a thouſand poliſh'd Ivory Balls be placed in a hollow Tube fifty Feet long; if now the firſt of theſe is ſtruck forward, at that very inſtant of time the laſt of them will depart from the laſt but one, while the intermediate ones are at reſt. In this Experiment all theſe intermediate Spherules muſt have changed their ſpherical Figure by the Impulſe, and recovered it again in ſo ſhort an inſtant of time, except the laſt, which flew off from the reſt, as having no other to reſiſt it. Hence therefore the moſt hard Bodies in a very ſmall Compaſs may propagate Motion *ad infinitum*. For ſince there is no Difference in an Aſſemblage of a thouſand Spherules, there will be likewiſe no Difference obſerved in ten thouſand of the ſame Ivory Globules extended in a Line even a Mile long, and alſo in a Line continued even from the Earth to the Moon; but in a Canal or Tube which is filled with an inelaſtic Liquor, an Impreſſion will be propagated from one End to the other almoſt in the ſame manner; for being received at one End, it will be inſtantly continued to the other. It matters not therefore, whether the Matter with which the Nerves are filled be elaſtic or not, or whether they be altogether ſolid; ſince it is evident from what has been ſaid, that ſuppoſing either of theſe to be true, the Senſations may be eaſily and inſtantly propagated to the Brain.

§. 570. In the mean time different Ideas ariſe from theſe Impreſſions according to the Variety of *Objects* [1], the Difference of the *Nerve* [2] affected, and the particular Fabric of the ſenſitive *Organ* [3], with the different Part of the Medulla of the *Brain* [4] from whence the

the Nerve comes; as alſo according to the various *Degrees* [5] of Motion with which the Objects are applied to or act upon the ſenſitive Organ: according to all theſe particular Circumſtances, a different *Idea* [6] is raiſed and perceived by the ſenſible Intellect; and notwithſtanding the Idea repreſents *nothing* [7] either of the Action of the Object, or Paſſion of the Organ, yet the ſame Action of the ſame Object upon the ſame Organ is always attended or followed with the ſame Idea; ſo that the Connection of theſe Ideas follows the Nature or Diſpoſition of the ſame ſenſitive Organ, juſt as if the Idea perceived was the Effect of the Action of ſome Object upon the ſame Organ.

[5] Differing with reſpect to Figure, Magnitude, Denſity, Hardneſs, Motion, *&c.*

[6] Every Nerve ſeems to be endowed with a peculiar Faculty, by which it is enabled to perform or exerciſe the particular Senſe for which it is deſigned. A red Colour has nothing like itſelf throughout all the things of Nature; nor can it be perceived any other way than by Viſion with the Eye. There is therefore a peculiar Faculty in the optic Nerve, by which the Perception of a red or any other Colour may be repreſented to the Mind: in the auditory Nerve there is an Aptitude to repreſent Sounds, and in each individual Nerve there is a Power or Diſpoſition peculiar to itſelf.

[7] Where the Nerve perceives it is almoſt conſtantly expanded into a Pulp; not excepting even the Organ of Touch and Taſte, as well as Hearing; but then the Organ placed before the Nerve is various: ſo that before the optic Nerve is placed

ced the Eye, a dioptrical Machine; before the auditory Nerve is placed the Ear, a phonergic Organ; the Nerves of the Tongue riſe up and are received into perpendicular erect Vaginæ. But in other Parts the Senſe of Touch or Feeling is performed by a more ſimple Mechaniſm. Theſe Laws of Mechaniſm were prefixed by the Creator to his own Work, which we diſcover by Obſervation; and therefore the Diverſity of Senſes ariſes from the Diverſity of the Organ placed before the ſentient Nerve.

4 It is an Opinion of my own, from which I cannot eaſily depart, namely, that there are diſtinct Parts or Provinces in the common Senſory for the different Senſes, in the ſame manner as we obſerve a diſtinct Organ deſtined to every external Senſe. *Euſtachius* firſt plainly demonſtrated, that the Origin of the Nerves in the Brain was not confuſed; but that each Nerve aroſe from its proper Part of the Brain, by Fibres diſtinct and ſeparate from the reſt of the Nerves. Hence it ſeems probable, that each Set of Ideas dwell at the Origin of each particular Nerve in the Brain; thoſe of Sound about the Origin of the auditory Nerves; thoſe of Light about the optic Nerves, *&c.*

5 By an intenſe Light the Eye becomes blinded and painful, inſtead of being rendered capable of ſeeing. The very great, ſwift, and ſtrong Report of a Hand-gun, which has a long and ſtrong Barrel, almoſt breaks the Membranes of the Ears, the Report being much more dangerous in this reſpect than that of the low and grave Tone of the largeſt Cannon; even there are more than a few Inſtances of the Membrane of the Tympanum broke by theſe Sounds. Bodies of too ſtrong a Taſte or being too roughly rubbed upon the Tongue, excite Pain inſtead of Taſte in that Organ; and the ſtronger Odours

Odours excite Sneezing. A Roſe ſtrongly preſſed againſt the Noſe does not ſend forth its pleaſing Odour; and again, the Tongue which in a healthy State is capable of taſting, perceives nothing but Pain when excoriated, even from the moſt agreeably taſted Objects. On the contrary, the weakeſt Sounds do not at all affect the Ear, *&c.*; ſo that a determinate Degree of Motion or Force in the ſenſible Object is required, which it ought not to exceed or fall ſhort of, in order to excite a juſt Idea in the Mind by acting upon the ſenſitive Organ.

[6] In the common Senſory there is no other Change perceived than that of a gentle Preſſure; as when we hear, the gentle Tremor of the Membrane of the Tympanum goes and returns.

[7] When any Sound is publiſhed in the Air, the Ears of every Creature are affected thereby. There is not any Perſon or Creature who does not deteſt the Noiſe or Report of a Muſket; nor is there any one ſkilled in Muſic who is not delighted with the harmonical Conſorts. All People therefore perceive almoſt the ſame Idea from the ſame Object. But in ſuch a common Idea there is nothing truly belonging either to the acting Object or the affected Organ; nor do our Ideas ariſe from a Knowledge of the Figure, Bulk, *&c.* compared with the Figure, Bulk, *&c.* of the Object; though theſe Changes of the ſenſitive Organ are at preſent acknowledged by every one to be different from the Ideas which they excite, except *Spinoza* and the *Epicureans*. What Light is, remains a Myſtery to every Mortal, and what the Eye is, but few are acquainted with; and yet the Huſbandman ſees as well as the Philoſopher. A knowing Phyſician who applies a Particle of Sea Salt to his Tongue, perceives not only the ſaline Taſte, but alſo underſtands that the diſſolved ſaline Particles penetrate through

through the Pores of the membranous Vaginæ, and velicate the nervous Papillæ of the Tongue; yet he does not taſte the Salt in the leaſt better than the moſt ignorant. I have ſeen Philoſophers extremely well ſkilled in the Theory or mathematical Part of Muſic, who yet were very bad Performers; as, on the other hand, I have obſerved excellent Performers whoſe Heads were made up of nothing more than muſical Ears. Senſe or Underſtanding is not therefore the Perception of the Actions of Bodies without us. When we think we ſee a red Colour or recollect the Idea of the ſame Colour, we neither think nor ſee any thing which exiſts in reality. But if we recollect ſuch an Idea, there is the Repreſentation of coloured Rays to the Mind reflected from ſome Body, and falling upon the Surface of the Cornea. When we perceive Pain from burning, we do not immediately perceive that which is applied to the Organ; for then any one would believe, that the Nerves ſent from the Brain to the Hand were divided by certain ſolid and moſt minute ſmall Bodies moved with a great Velocity; but then this is what no Perſon can know but by much Uſe and Experience in the nature of things, becoming wiſer by various Diſciplines and Reaſonings. But the Idea of Pain which we perceive, neither expreſſes the Burning nor the Diſſolution of the Nerve; for there is only one Intelligence given to the Mind of a preſent Evil, agreeable to the good Will of the Creator. Senſation therefore is nothing either in the Object, or the Nerve affected; but a certain Idea which God has determined or aſſigned to each particular Change in the corporeal Senſory. This Doctrine is alſo acknowledged by Sir *Iſaac Newton* in the laſt Edition of his *Optics*. But we are to obſerve this by the way, that by a certain

Law

Law a determinate Idea is raiſed by a definite Change in the corporeal Organ; ſo that the ſame Action of the ſame Object upon the ſame Organ duly diſpoſed, always excites the ſame Idea. Sugar applied to the Surface of a healthy Tongue can raiſe no other Idea than than that of a ſweet Taſte, and Cloth of a determinate Dye or Surface being expoſed to the Sun will raiſe no other Idea than that of Scarlet. Notwithſtanding therefore we perceive nothing of the Object nor of the Organ, yet the Idea raiſed in the Mind from the ſame Action upon the ſame Organ is always alike. You may perhaps object that this Opinion leads us to Pyroniſm or Scepticiſm; for if we do not ſee the things themſelves nor hear the Sounds by which we are affected, what Knowledge can we have concerning the Truth of any thing? But this Objection may be ſolved by a familiar Inſtance. Suppoſe yourſelf to be born in *America*, and never to have heard a Word of *Latin*; if now you hear me ſpeaking in that Language you will certainly perceive no Ideas from my Words, notwithſtanding your Ears receive the ſame Impreſſion with my own, nor will you learn any thing which I teach, or think the ſame Thoughts which I think, or which yourſelf would think, if you had learned to ſpeak *Latin*; for in this Caſe there is no Connection betwixt our Ideas and the Words. An *European* Gentleman in *India* ſent ſix Apples by a Negro Servant to his Friend, with a Letter expreſſing the Number of them; but the Servant eating three of them by the way, delivered only as many; the *European*, fond of the preſent, aſked the Servant why he did not bring the ſix Apples which were given into his Truſt? This was denied by the Negro; but being at length convicted, he acknowledged the Fault, not without great Surprize, that a piece of white

white Paper marked with Black ſhould be able to make ſuch a Diſcovery. The ſame thing happens with regard to the Sight; for a ſkilful Limner takes a piece of Vitriol, which by mixing together with Galls and Gum Arabick he forms into Ink, and upon a piece of Paper, which is ſupplied to the Limner by another Artiſt, he draws two Men with this Mixture, who are duelling together with the greateſt Contention of Body and Mind; but one of theſe ſhadowed Men falls down, being run through. All that ſee this Table, if it is the Work of an Artiſt, will be moved with Horror, and think of Death, though at the ſame time they ſee nothing but fine Duſt diſpoſed in certain Order, all the reſt being ſupplied by the Mind. If a Noſe of a particular Figure is drawn upon a Wall, whenever that is ſeen by a Perſon, they will think with themſelves whoſe Noſe is this. Our Senſes therefore teach us an infinite Number of Things which are not exiſting in Nature without us, and which have nothing in common with the Things themſelves. The whole Definition therefore of *Spinoza* muſt fall to the Ground, by which he calls Senſe a Motion of the Mind generated from the Motion of a Body; the Mind being a thinking Part of the Univerſe, and the moving Body an extended Part of the Univerſe. All our Senſations therefore are owing to that Diſpoſition of the Mind which was given to it by the Creator, who has ſo ordered it, as not to be capable of ſeeing the Object which the Eye ſees, and yet that it ſhould form the ſame Judgment as it would if it had received or collected the luminous Rays themſelves. But yet our Senſes do not deceive us, for in reality the Rays are reflected and painted in a certain Order upon the Retina. But all our Errors ariſe from the Haſtineſs of our Judgment,

by

by which we conclude, for Inſtance, that a red Colour is in the Body itſelf, becauſe it ſeems to us to be ſo. It may be then aſked, What is Senſation? In ſhort, we know not. We only know this, that in our Body there are certain Organs adapted to receive certain Motions; and that theſe Organs being continued into the Brain, the Mind there perceives and judges of the Objects, as if it perceived them immediately itſelf. But to explain the Connection of all theſe corporeal Actions with the Mind itſelf is not within the Power of Man, and much leſs is it our Buſineſs in this place.

§. 571. The Diverſity therefore of our Ideas does not ſeem to depend only upon the various Manner in which the Extremity of each Nerve is *diſpoſed*[1] in its proper Organ, but upon a great many other Things, not as Cauſes, but Conditions aſſigned by the moſt wiſe Creator.

[1] I had formerly many Diſputes with my Friend *Raw* upon this Subject; for he was of Opinion, that every Nerve expanded like the Retina in the bottom of the Eye would be capable of ſeeing, ſo that if the auditory Nerve was inſerted in the Eye, it would diſcern Objects by Sight; and, on the other hand, that if the optic Nerve was inſerted into the Ear, and expanded within the Veſtibulum under the Membrane of the Feneſtra ovalis, it would be capable of hearing. Even he goes further, and thinks that the pulmonary Nerve would be capable of ſmelling, if Nature had framed it in the ſame manner with the olfactory Nerve. But it does not ſeem barely ſufficient for the Tremors of Objects to be communicated to the Nerves,

but an infinite Number of other Circumſtances muſt neceſſarily concur, in order for the diſtinct and reſpective Ideas to be raiſed from Objects in the Mind.

§. 572. Ideas thus perceived in the *Mind*[1] generally excite by their Impreſſions either Joy or Sadneſs, or neither of them; ſo that their Impreſſions cauſe either an Indifference, a Love or a Hatred towards the Object by the Action of which the *Idea*[2] was excited.

[1] Namely, the Perception or Underſtanding. This is the ſimple Knowledge of things without relation or regard to any other thing, as, for Inſtance, a Circle which the Geometrician thinks upon. But generally this Idea or Repreſentation of the Object excites ſomething more than the bare Repreſentation, which is not a ſimple Idea or Perception, but a Determination of the Will with reſpect to the Idea. When the Will is deſirous of retaining the Idea, the Object is then ſaid to give Pleaſure or Joy, there being a perfect Conſent or Harmony in the Senſation. If we trace this pleaſing Idea to its Cauſe, we are obliged to love the Object whether we will or no; for we wiſh that the Thing might remain united to us, nor do we chuſe to think rather upon ſomething elſe; and this we call Love: thus *Mars* ſees and covets the Object ſeen. But when, on the contrary, the Mind is diſpleaſed with retaining the Idea, there follows a Senſe of Sorrow or Pain, and then it is impoſſible to think with Pleaſure upon the diſpleaſing Object in our Minds, and therefore we deſire to remove the ſorrowful Object or Cauſe from its Exiſtence in Nature and in our own Minds, that

that we may not think upon the ſame; and this is called Hatred. When I deſire an Enemy to be removed, I only requeſt it that I may not think of the Perſon, which if I obtain I ſhall be quiet and compoſed; for merely from the Idea of that Man, a Senſe of Deſtruction as it were riſes in my Mind, which I am obliged to deteſt. From theſe two Affections or Inclinations of the Mind all others are derived. The Love of a preſent Object is Joy, and of a paſt Object a pleaſing Recollection; and the Love of a future Object is Deſire, which we call Hope, when there ſeems to be a Poſſibility of obtaining the Thing deſired. A preſent Evil excites Sorrow and Hatred, one that is paſt excites a Recollection of Anger, and a future Evil excites Fear. The other Affections of the Mind are rather Degrees of Love, according as the Object is either preſent, paſt, or future; or elſe Degrees of Hatred with reſpect to ſomething paſt, preſent, or to come. All theſe Affections of the Mind which move us with ſo much Vehemence, are called by the general Name of Paſſions of the Mind; namely, that ſenſitive or thinking Being, whoſe Compliance we ſo often pray for with Tears, and which diſturb the Will or Judgment, namely, that Part of the Mind which ought to direct it to the Object. But neither are Paſſions of the Mind the Reſult of Reaſon, nor are they ſubject to Reaſon.

Non amo te Voluſi, non poſſum dicere, quare:
Hoc, unum poſſum dicere, nec amo te.

Et alius Poeta:

——— *Video meliora proboque,*
Deteriora ſequor. ——— ———

OVID. in Met. VII.

But even one who underſtood theſe Matters better than *Socrates* or *Epictetus* has pronounced, if you ſee a Woman and luſt after her, it is the ſame thing as if you had committed Adultery with her, *Matth.* v. 28.

[a] Such an Indifferency is there in the Mind, when it perceives the Idea of a Circle, of a right Line, of the Air, *&c.* The Senſes, both external and internal, are Changes of the Thoughts in the Mind. For Inſtance: I ſee a red Colour, and I can think that I ſee ſuch a Colour preſent when it is not. The internal Senſes differ from the external, not in Thought or Ideas, which is common to them all, nor in the Change of the common Senſory, but in the Abſence of external Objects; that is to ſay, when the ſame Changes of Thoughts or Ideas ariſe, as if they came from external Objects changing the ſenſitive Organs, though at the ſame time there is no ſuch external Cauſe preſent to move the ſenſitive Organs. For Inſtance: I ſee a Negro, and I imagine ſtrongly that I ſee the ſame Negro; in this Caſe the Idea of the recollected and preſent Object are not at all different. In this indeed they differ, that the Senſe is external when the Negro ſtands preſent before me, but internal when I repreſent the ſame Idea of the Negro to my Mind by Thought. Does it not therefore follow, that both theſe Senſations are produced in the Mind with this Difference, that the one proceeds from an external Cauſe, and the other from an internal Cauſe or Change made in the Senſory itſelf.

But why has every Age of Man his particular Inclinations? This will appear from reading the Lives of thoſe who have freely followed the Inclination of Nature without any Reſtraint, as Kings, *&c.* for ſuch are in the Time of their Youth full of Amours, Liberality and Benevolence; but as

Age

Age advances they become Warriors, and affect a great Name; and when Age declines they become covetous, and with Avarice they are likewiſe cruel. So little Influence has Reaſon upon the Paſſions, except in thoſe few which alone deſerve to be termed happy.

§. 573. But we are ſo framed, that this Condition of the Mind either of Love or Hatred is apt to excite ſuch *muſcular Motions* [1] in the Body, as may unite the Object of Joy either to the Body or to the Mind; or by the Efficacy of which Motions the Idea may be ſo removed, that the Sorrow or Grief which accompanies its Preſence ſhall quite diſappear.

[1] All the Muſcles are moveable at one and the ſame time. In ſevere Anger we ſuddenly grow hot, and immediately deliver what we think with Vehemence by the Tongue, which is by *Euripides* called the Servant of Anger. Thus *Achilles* being anger'd at *Agamemnon*, firſt expreſſes by his Tongue the Uneaſineſs, and then threatens by Geſture, when he ſnatches up his Weapons with his Hand. Nor is there any Delay, but the whole Body is agitated with ſwift and convulſive Motions; all which tend to the Deſtruction of the diſpleaſing Object. For the whole Body is ſo diſpoſed, that all the Muſcles ſuddenly operate at the ſtrong Idea of a pleaſing or diſpleaſing Object which affects the Senſes; by which the former is endeavoured to be retained, and the latter to be removed, as being the Cauſe of Anger. If a Father ſees his Son tumble into the Water, with what a Violence are all his Muſcles ſhook without Deſign, in order to deliver his beloved Child from the Fate of the

Water. If the Finger is burnt, at that Inſtant all the Muſcles in the Body are convulſed to withdraw it from the Fire. But how come the Muſcles to be made thus acquainted with the Danger? No one will pretend to explain this.

§. 574. But ſince theſe muſcular *Motions* [1] are excited by means of the Spirits or Juice of the Nerves, propelled from the Brain into the Muſcles; it is therefore evident that the Spirits have a free Courſe from their Origin in the Brain, from every Point thereof, even to the Muſcles which are under the Influence of the Will: Hence it follows, that the common *Senſory* [2] is a Part of the Brain, where all theſe Points are collected together; and that therefore it appears to be in the Medulla of the Brain in the Head.

[1] In all Paſſions of the Mind there is, 1. A Repreſentation of the thing placed without us. 2. A concomitant Idea repreſenting the thing perceived, and exciting the Inclination or Will. 3. A Motion in the Muſcles tending to retain the Good, or remove the Evil which is perceived. Hence therefore the Seat of the Paſſions of the Mind is where the external Object firſt impreſſes its Idea; and therefore the Seat of theſe Paſſions and of the ſentient Mind muſt be in the common Senſory. Hence all Paſſions of the Mind are ſuppreſſed in a profound Sleep which is free from Dreams; and in an Apoplexy all the Ideas of Joy or Sorrow are obliterated.

[2] The Senſorium is that Part of the Body where the ultimate Actions of all the Nerves terminate, ariſing by the ſeveral ſenſitive Organs from Bodies placed

placed without us; and in which Part the Perception of theſe Actions is perform'd, ſo as to determine the Will either to Love or Hatred; and from whence at length the Influence of the Will firſt begins, according to its Determination by the ſentient Nerves to operate upon certain Muſcles, by which the pleaſing or diſpleaſing Object is either retained or removed. In this Part therefore the Senſations of all the Nerves terminate; and here alſo ariſes that Power from whence Love and Hatred operate upon the whole Machine, and upon all the Muſcles which are ſubject to the Influence of the Will. This common Senſory ſeems to be ſeated where the ultimate lymphatic Arteries in the Cortex of the Brain firſt unite themſelves to, and fill the Beginning of the Nerves with Spirits throughout all the Ventricles and Inequalities of the Brain, *&c.* Something of the like kind ſeems alſo to have been intended by *Vieuſſens*, which he calls by the Name of Centrum ovale. But the Territories or Limits of this common Senſory ſeem to be very large and various, ſo that each Nerve has its particular Part in the Brain where thoſe Ideas dwell which were conveyed by the ſame; the Ideas of Odours about the Termination of the olfactory Nerves, of Colours about the ending of the optic Nerves, and of Motion about the Nerves ſubſervient to the voluntary Muſcles, *&c.* In this Part it is that the great Commerce betwixt the Body and the Mind ſeems to be placed; as we are likewiſe taught by Experiments. For if a ſmall Artery be burſt in the Ventricles of the Brain in a healthy Perſon, in the ſame manner as a ſmall Artery of the Noſe we ſee burſt many hundred times, in that caſe ſome Blood being extravaſated into the Cavity of the Ventricles will preſs upon the arched Origin of the Medulla, whence an Apoplexy follows (§. 284.),

the ſimple and primitive Ideas of things are aboliſhed, and the concomitant Affections of the Mind which accompany thoſe Ideas are alſo ſuppreſſed, together with the Motion of the Muſcles. This Seat of the Mind therefore is not in the pineal Gland, as *Carteſius* would have it; for who can believe that ſo many thouſand Nerves all deſtined to different Senſations and Motions can take their Origin from ſo ſmall a Particle? Nor yet is the Seat of the Mind in the ſpinal Medulla or in the Cerebellum (§. 600.), but only in the arched Medulla which encompaſſes the Cavity of the Ventricles in the Brain, as *Galen* in ſome meaſure rightly imagined, only he erred in believing that the Cavities of the Ventricles were filled with animal Spirits, which we demonſtrate to be perpetually moved in cloſe Veſſels. And therefore our Humanity or Intellects depend upon the healthy Diſpoſition of this Part of the Brain.

§. 575. The more *diſtinct* [1] the Action of the Object is upon the common Senſory, the more diſtinct and clear will be the Idea thereby produced.

[1] By diſtinct, we underſtand here when one ſimple Object acts at one time upon the whole common Senſory without being diſturbed by any other Object at the ſame time; for by that means a ſimple Thought is produced, and there is but one Perception. For Example: Suppoſe a Triangle of a red Colour which alone I ſee illuminated in a dark Place; for then that will be repreſented moſt diſtinctly in all its Parts to the Mind. When I ſurvey any minute Object very accurately with a Microſcope, the chief Art conſiſts in placing the Object on a Piece of very black Wood, that ſo the Eye

Eye may ſee nothing more than the Object itſelf. A Geometrician who is intent upon ſome difficult Problem thinks upon nothing but upon the Idea of his Problem, which that it may not prove too difficult or diſturb his Mind by its Complexity, he divides into ſeparate Parts, and conſiders each of them alone. Hence thoſe who dedicate themſelves to one Study, are uſually but half-witted in the reſt. No one is better qualified than a melancholy Perſon for compleating any particular Hiſtory; for ſuch a one is from a natural Diſpoſition inclined to adhere firmly to one Subject. Even Fools themſelves can perceive one thing or Object as well as thoſe who are in their right Mind; but when Ideas are to be continued in a Chain they fall into Error.

§. 576. The more *vivid*[1] the Action of the Object upon the common Senſory, the more clear is the Idea thence excited.

[1] This is the ſecond Law of Perception. Such a Triangle as before-mentioned will be difficultly ſeen in the Duſk of the Evening, but it will be perceived more diſtinctly if the Light is a little increaſed, but beſt of all when illuminated by the Noon Sun. A Perſon dwelling in the Country and hearing a Rumour at a great Diſtance, perceives nothing diſtinct enough, but by attending and ſtretching his auditory Organs to an harmonical Tenſion, the Sound becomes by degrees more vivid, and he hears diſtinctly. Hence in the microſcopical Obſervation of a very minute Object which is to be diſtinctly examined, it ought to be illuminated with a ſtrong Point of Light, while every thing which ſurrounds it is perfectly obſcure. This is one of the greateſt Secrets in theſe kinds of Experiments ſufficiently known to but a few.

§. 577. The oftener the Action of an Object *renewed* [1] upon the common Senſory, the more clear is the Idea.

[1] This is the third Law of Perception. Children are uſed to get their Taſk not by thinking only, but by repeating the ſame Word many times together with a loud Voice, that from thence may ariſe an Idea almoſt indelible; by which means they are able to read that without Book which they read ten times within it, which is certainly a very bad Method of learning.

§. 578. Alſo the more remote the Action of the Object is from all others upon the common Senſory and the more *unuſual* [1], the more vivid is the Idea thence expreſſed.

[1] This is a fourth Law, which any one may experience the Truth of by Experiment; for if you endeavour to recollect what happened in the moſt early Days of your Youth, regiſtering them down upon a Piece of Paper, you will find that they are Ideas very diſtinct from all others, unuſual, and generally terrible. The Idea of an evil Spirit with Horns vomiting Flame propoſed by a Nurſe to a petulant Child, a black Dog, a Negro, or the like. We experience, that the Ideas of every Day are effaced by thoſe of the next of the ſame kind. *Spinoza* was a melancholy Man, and therefore he died of a pulmonary Conſumption, but was not in the leaſt given to Superſtition: but he confeſſes, that when he ſaw ſome of the Inhabitants of *Brazil* ſeven Feet high with yellow Hair, ſuch as is wore by that Nation to a great Length; it made ſo ſtrong an Impreſſion, that he had always the

the ſame Ideas in his Dreams, and could ſcarce efface the ſame in the Day-time by the moſt ſtrenuous Meditation upon other Subjects. An *Indian* Man who ſees an *European* Perſon for the firſt time, every way like himſelf but of a different Colour, ſuch as he had never ſeen in Man before, neither will that *European* ever be forgot nor the Place in which he ſaw him as long as he lives; ſo ſtrong and firm is the Impreſſion of Objects, whoſe Ideas are very different from others.

§. 579. If therefore the Condition impreſſed upon the common Senſory remains fixed there ſo *firmly* [1] that it cannot be changed by the ſupervening Action of other Objects, the preſent Idea will then remain an inſeparable Companion of that Condition in the common Senſory.

[1] This is made in the common Senſory. That phyſical Cauſe which makes the Mind perceive ſuch an Idea without thinking upon any other, is ſo ſmall an Entity that ſcarce any thing can be conceived to be leſs. Of theſe ſame Beings if one exceeds the reſt but a ſmall degree in Strength, then the laſt only remains preſent in the Mind, while the reſt vaniſh, which we call Contemplation; namely, when we think ſome time attentively upon the Idea perceived, which is the way to retain the preſent Idea; for in proportion as that Impreſſion exceeds in the common Senſory, ſo much the longer will that Idea remain preſent in the Mind. This I have experienced by receiving the Focus of a Burning-glaſs into my Eye; for by that means the Image of the Sun has been preſent in my Mind for ſeveral Hours. From this Obſervation Phyſicians may explain all Diſ-

orders

orders of the Imagination. For theſe Imaginations ariſe when any impreſſed Idea is ſtrongly retained and excited by ſome internal Cauſe, as may be eaſily proved by Experiment; for if in a dark Place you turn the right Eye as much as poſſible towards the left Side, and then gently touch the ſame Eye with the End of the Finger, you will then perceive the Idea of a conſiderable Light or great Flame. But in this nothing more was done than changing the Situation of the Retina by tranſmitting a ſmall Concuſſion by which there aroſe a clear Repreſentation of a Flame. The ſame thing is experienced, but with more Inconvenience, when the Fiſt is ſtruck againſt the Eye, by which means Sparks of Light ſeem to fly out ſuddenly from that Organ. But we are aſſured even to mathematical Certainty, that in ſo dark a Place there was no Light, and yet it will be almoſt impoſſible to perſuade yourſelf from believing that you did not ſee Light. Certain it is that there was no Cauſe of the Light ſeen exiſting without the Eye, and yet the internal Senſe is as vivid as if the Light itſelf ſtood before the Eye. If again, ſuch a Cauſe ſhould produce a like Motion not in the Eye but in the Brain itſelf near the common Senſory, where the optic Nerve takes its firſt Origin: I ſay, if ſuch a Motion be there communicated by the Vibration of an Artery too much diſtended, there will be the ſame Idea of Light perceived as before by preſſing upon the Retina, even though there is no Light exiſting without before the Eye. When any one of the ſmall Arteries ſpread upon the Cavity of the Tympanum has too ſtrong a Pulſation, it excites a Noiſe hardly diſtinguiſhable from that which remains ſometimes in our Ears after the Exploſion of ſome very large Cannon. I know at that time that there is no Cannon exploded, yet I cannot

cannot avoid hearing as it were the ſame Noiſe. A black Dog is with reſpect to my Eye nothing more than a certain inviſible Space circumſcribed by a Line of a particular Figure, affecting the optic Nerve in a particular manner; now when this black Dog ſtands before me, the Cauſe of that Idea is without; but when the ſame Cauſe acts within, I have nevertheleſs the ſame Idea as in the former Caſe: nor will the Idea ariſing from without differ from that ariſing from a Change in the Senſory within; and if ſuch an Idea ſhould be ſtrongly rooted in the Senſory, it may remain a long time, and will not be eaſily effaced by the Impreſſions of new Ideas.

§. 580. Or at leaſt the ſame Idea returns, either in Obedience or contrary to the Will, by means of ſome *ſimilar* [1] Cauſe or ſimilar Idea; which returned Idea being accompanied with a *Conſciouſneſs* [2] of the like thing formerly perceived is called Memory.

[1] When two things exiſting together in myſelf have impreſſed the Cauſe of ſome Idea by operating together and conjunctly, ever after one will revive the Idea of the other, or by recollecting the one the other will alſo recur to mind. If a Child is ſent for the firſt time to School, and is ſeverely puniſhed with the Ferula by the Maſter, and is afterwards educated by the indulgent Parents out of all Danger of Stripes, he will certainly never paſs by the School even when he is an old Man without recollecting the Idea of the Sripes which he there received. If Robbers attack a Traveller in a Wood near an old Oak, and put him

him in Danger of his Life, if he ſhould ſee the ſame Tree fifty Years afterwards, it will excite in his Mind the whole Hiſtory, and renew the whole Chain of Ideas which then paſſed; even ſo as to make him tremble, though there is not at that time any juſt Cauſe for Fear. If one is at a loſs for ſome Verſe formerly learnt, for Inſtance, in *Virgil*; if a Friend reads the preceding Verſe, you will ſay that is not it which you want; but upon repeating the firſt Word of the next, all the reſt of the Verſe naturally follows in your Mind. I know a Perſon who had all the *Iliads* of *Homer* by Memory, ſo that if any one of his Companions repeated a Verſe, he could add the following Verſes in the ſame Order as they were to be found in that Author, without the leaſt Reaſoning or Heſitation. He had formerly received the Impreſſions of thoſe Verſes in their determinate Order, ſo that now when one of their Ideas is excited it continually recalls another, and that the next which followed in Succeſſion at the firſt Impreſſion. If therefore two ſtrong Ideas are impreſſed at one time, one will never be recollected without drawing in the other; and this is altogether a ſurpriſing Law which the Creator has prefixed to the human Mind.

[2] Without Conſcientiouſneſs it is not properly Memory, but only a ſimple Recollection like that of Fools; and in general, Men who are of the moſt happy Memory are the leaſt apt to take in new Counſels or Doctrines.

§. 581. But all this reſults only from that ſimple Condition of the common Senſory, which is in effect nothing more than a *mechanical*[1] Diſpoſition or Change.

All

1 All this depends upon the eaſy Return or Recollection, by which the Mind becomes conſcious that it had formerly ſuch Ideas preſent; and this is Memory, which the Ancients called *Minerva*, or the Mother of *Minerva*. Take away Memory from a Perſon, and he becomes a mere thinking Machine. If our Humanity was placed altogether in thinking, as *Carteſius* ſuppoſes, we ſhould be a metaphyſical Point or Atom ſpontaneouſly produced, at preſent thinking and afterwards ceaſing to think, without a Continuation of Thoughts. But to our Humanity or Intellect belongs not only Thought, but alſo the Remembrance of thoſe Thoughts, which we call Memory. The Mind would not underſtand that it exiſted the preceding Moment without this Faculty, nor would it know any thing but what exiſted at the preſent moment of time; but as that moment is continually vaniſhing, the Mind would thus know nothing. But ſince we are thus endowed with Memory, we are capapable of retaining and knowing thoſe things which happened a thouſand Years before; for an Aſtronomer knows that an Eclipſe of the Sun will follow ten Ages hereafter, with as much Evidence and will determine the ſame with as much Certainty as we can be aſſured of an Eclipſe that paſſed ten Ages before recorded in the Almanacks, or which will be ſeen in the Heavens ten Ages hence by Poſterity; nor would there be ſo much as one Art ſubſiſting among us if the Memory was deſtroyed. In order to explain this further, we are to obſerve that Cogitation and Memory are diſtinct, the former belonging to the Mind, and the latter depending on the Body. They who are furniſhed with the beſt Faculty of thinking, publiſh their Thoughts without any Uſe or Advantage if they are deſtitute of Memory. We read of a certain *Spaniſh* Tragi-

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cal Poet who had wrote ſome excellent Plays, in which he had pleaſed himſelf as the Poets uſually do; but the ſame Poet being afflicted with an acute Diſeaſe loſt all his Memory, inſomuch that he could not remember his Alphabet; ſo that when he began to recover, he was obliged to learn his Letters, grammatical Rudiments, and Elements of things over again; which is alſo reported of an old Grammarian at *Athens*, that he might by degrees recover any Part of his Learning which he had loſt. When this Poet was well, they gave him his own Verſes which he had compoſed before his Illneſs; but he could by no Argument be perſuaded that this unknown Work which he ſo highly praiſed was performed by himſelf. At length his Senſes being reſtored to their former Integrity, he compoſed new Verſes, and was with ſome Difficulty brought to believe, from the Analogy and Genius of the old and the new Drama, that the former was alſo his own Performance. This Man had certainly a worſe Memory than *Pythagoras*, who could recollect that in the *Trojan* War he was *Euphorbus*, and that his Shield which ſome Ages before was carried by another Man, was hung up in the Temple. Therefore that which is not retained in your Memory is nothing with regard to yourſelf; ſo great is the Advantage of this Faculty given us by the Creator.——But this Faculty of Memory, as far as we know, depends upon the Body. Indeed *Socrates* bids us doubt, when he ſays, that we gueſs more than we know concerning things to come. In the mean time if this Law is eſtabliſhed, namely, if the Memory reſults altogether from the Diſpoſition of the Body; in that caſe if the Thoughts or Ideas are ever ſo excellent, remove their Connection and it will be Madneſs. Thus Fools conceive right Notions, or think truly

of

of every particular thing or Object, and are capable of giving a right Anſwer to a ſimple Queſtion; but they err in the Connection of their Ideas, their Head running from the Ox to the Aſs immediately, without remembering what they thought of before. But this whole Connection of our Ideas reſults from the mechanical Diſpoſition of the common Senſory, or the firſt Origin of the Medulla of the Brain; for the Memory may by a mechanical Cauſe be deſtroyed for a time, as for Example, by a Diſtenſion of the Veins from drinking too great a Quantity of Wine. When a Perſon is in a Sleep he is quite deſtitute of all Memory; and frequently if an Apoplexy is removed without killing the Patient, yet it often deprives the Patient of his Memory during the reſt of his Life.

§. 582. Ideas or Thoughts may therefore ariſe, as well from corporeal Cauſes within the Body, however latent, affecting the Nerves, Spirits, and Brain, in the ſame manner as to excite the ſame Ideas, as if they aroſe from external corporeal Cauſes. And this Diſpoſition is called the primary *Imagination* [1] or Fancy.

[1] By this Name we underſtand the Perception of Ideas ariſing in the Mind from internal Cauſes, like thoſe Ideas which are uſually produced by external Cauſes; for when the like unknown mechanical Change is made in the common Senſory, the ſame Idea is produced in the Mind as if the like Change in the Senſory aroſe from ſome external Cauſe, which is not here ſuppoſed to have any Action. This Faculty the Ancients called the Fancy, and the Objects of it Phantaſmata or empty

Appearances. For Example, I ſee an Object exiſting without me, a Flame; and this is called Viſion, an external Senſe, becauſe by the common Conſent of all Men this Idea or Viſion is raiſed from an external Object as the Cauſe. But another Perſon who preſſes his Eye with his Finger, will alſo believe that he ſees fiery Sparks, when there is no ſuch real Cauſe exiſting without, ſince other People ſee no ſuch thing; and this Idea is repreſented as ſtrongly and clearly to the Mind when diſeaſed, as if it aroſe from Fire exiſting without and placed before the Eyes. The Idea ariſing from the real Object is referred to the external Senſe, and the Perception of that Idea to the primary Imagination. But theſe Ideas are neither ſtrong nor eaſily lead the Mind into Error. Sometimes a Cauſe exiſting within the Brain, ſuch as extravaſated Blood repreſenting red Appearances to the Mind, cauſes the Idea of a Rainbow as if ſeen by the Eye; ſuch Rainbows ſeen in the Beginning of a Fever are uſually fatal to the Patient, though he be not as yet in Danger; according to the Obſervation of *Diemerbroeck*, ſuch a Patient ſays that he then ſees a Rainbow, but you on the contrary ſee nothing, for there is no Rainbow without the Body to excite ſuch an Idea: the Perſon may indeed be eaſily convinced that he is deceived, but then it will be found that the Cauſe exciting the Idea of a Rainbow is within himſelf; and that Cauſe will appear to be as real in the Patient, as the Cauſe of ſeeing the Rainbow is real, when the Sun ſends forth his Rays which are reflected to us from a watery Cloud.

§. 583. If now there is a ſtrong Remembrance of a ſimilar Idea excited formerly by the

the Action of ſome external Object, and at the ſame time the preſent Idea ariſing from the internal Diſpoſition be vivid, there follows a ſtrong Perſuaſion in the Mind, that the Cauſe exciting that Idea is then preſent without the Body; and this is called the *ſecondary* [1] Imagination.

[1] When the Idea of any thing in the Mind, for Inſtance, of a Book, is as ſtrong when the Object is abſent as it formerly was when the Object was preſent, then the Memory ſupplies the Idea of the Book, and repreſents it ſo ſtrongly to the Fancy or perceiving Part of the Mind, that we are almoſt obliged to believe we actually ſee the Book placed without us. But this ariſes from the Repreſentation of the Idea, which is produced by the preſent Action of an internal Cauſe with a ſtrong Memory of the ſame thing which formerly exiſted without us. This Imagination often obliges even wiſe Men eaſily to err and obſtinately to perſiſt in the ſame Error. I ſaw a young Man delirious by over-ſtudying himſelf, who imagined a fierce Dog continually before him; and the Image of that Beaſt had ſo impreſſed itſelf upon his Mind that he continually admoniſhed the By-ſtanders to keep away from that dangerous Creature, and could not be perſuaded by any means from believing that the Dog ſtood at his Feet. But when the Mind not only perceives ſuch an Idea, and believes it to be true, but is alſo joined by the Will which acts in conſequence according as the pleaſing or diſpleaſing Idea is received or rejected; we uſually call ſuch People raving mad. I ſaw a young Student delirious from a Fever, who believed that he was charged with a certain Number of Pieces of Money,

which he was to deliver to the Militia under the Penalty of a certain Puniſhment if he did not return to his particular Station and Office: but being negligently guarded, he jumped naked thro' the Window and betook himſelf to that Station which he imagined to be commanded him; where being found and brought home, he afterwards expired in a little time.

§. 584. If the Will in the common Senſory, and in the Parts ſtrongly cohering thereto, retains that State which it receives from the Action of a diſtinct and vivid Object, or if the Action of all other Objects is ſuppreſſed or totally effaced, while the former only is retained, this Action of the Mind is called *Attention* [1]; by means of which the Idea is rendered diſtinct, clear, vivid, and laſting, and is therefore the Parent of *Knowledge* [2], as being the *beſt* [3] way to attain it.

[1] Attention is a Continuance of the Imagination, or a Retention of the common Senſory, in the ſame State in which it was diſpoſed by the Idea which the Will endeavours to retain. Imagination is the viewing of a ſtronger Image than others derived from Objects. When the Mind is intent upon one Idea, all the other Parts of the common Senſory are at reſt, and that only is opened where the Idea reſides which we would repreſent to ourſelves as preſent; and this is Attention, which *Cicero* calls hearkening to a thing. When therefore every thing is ſilent and the Action of only one Object is received, then the Perception of that Object is as clear as poſſible. A Mathematician enquires how, for Inſtance, a Pentagon may be formed

formed in a Circle; and therefore he rejects all other Ideas and thinks only of the Properties of a Pentagon and Circle, and by that means eaſily finds a way of ſolving his Problem. Young Men frequently labour under this Defect, namely, that they cannot retain one Idea alone or by itſelf, without confounding or mixing it with other Ideas of a different Nature.

[2] *Socrates* and after him *Plato* imagined that the Mind left to itſelf for a Moment might be able to perceive things infinite and the moſt difficult, provided it attended only to the Idea propoſed. Thus Geometricians when they think upon any Propoſition, as, for Example, the Square of an Hypotheneuſe in a right Angle is equal to the Sums of the Sides of a Square, in that caſe they have the whole Demonſtration preſent before the Mind at one Inſtant, which is contained in numerous Propoſitions, and which would take up much time, and even many Hours, if any one would relate them in order. Yet are our earthly and mortal Organs inveſted with that divine Strength, that the Mind can perfectly underſtand when it drops Images which are confuſed or weaker than that which it is our Intereſt to conſider. *Franciſcus Vieta* a moſt profound Maſter in Algebra, and the Reſtorer of the Analyſis of the Ancients, received from the *French* King ſecret Tables, in which were contained the moſt private Counſels of the King of *Spain*; but the Writings were found to be in an unknown Character, not legible to any Mortal, and therefore they were delivered to *Vieta* to be expounded. He ſets about the moſt difficult Work, and for the Space of two Days neither eat nor drank, nor ſaw or heard any thing till at length riſing up ſuddenly he found out the whole Myſtery: ſo long a time was his Mind taken up

without attending to any other Object, that he might find out the one thing propoſed. *Archimedes* went into a Bath when the Problem of *Hierones* was propoſed to him concerning the mixed Gold in the Crown, which was ſuſpected to be worked up with Silver by the Artiſt; of a ſudden this great Mathematician obſerved the Water to riſe in the Bath upon his entering into it, and perceived that from this rough and indigeſted Idea of ſpecific Gravity he could ſolve the Problem; thus therefore perceiving the Problem ſolved as it were in a Moment, he jumped out of the Bath with Joy, and ran about naked, crying out, I have found it.

[3] It is not impoſſible for the human Mind to conceive ſome Object, as, for Inſtance, a Sphere to be preſent before the Eyes, and to tranſpoſe and examine the ſame all manner of ways, as plainly as if it was preſent. But this working of the Mind is very laborious, and therefore Mathematicians do not chuſe to charge the Memory with difficult Problems, but they draw certain Lines which do not indeed expreſs the thing itſelf, before they have prefixed certain Ideas to each Line, and by that means conſider them in order and in combination; whereas the Operation would be immenſely difficult and laborious if it was to be worked in the Mind without the Aſſiſtance of theſe Lines.

§. 585. From what has been ſaid we have a Knowledge of the five external Senſes, as they are commonly counted, together with the internal Senſes, as they are called; namely, the Memory, Imagination, or Judgment, Inclination, or Will, and Attention, to which ſome add *Hunger* [1] and *Thirſt* [2].

But

[1] But thus even Pain, Pleaſure, Titillation, and other Senſations ought by the ſame Rule to be reckoned among the Senſes when they are only different kinds of feeling, and may be commodiouſly reduced to Anguiſh, or Sorrow, or to Pleaſure which we call Joy.

[2] God has given Thirſt to Animals, that they might know one of their chief Wants. There is no Neceſſity to contrive Tortures, for none is more ſevere than Thirſt. *Lyſimachus* being inveſted by the Enemy gave a Kingdom for a ſingle Cup of Water, crying out, when he drank the coſtly Draught, ſo much coſt one ſingle Cup. God could not well entruſt us to ſupply our Wants by Reaſon, for we are led on too ſlowly by that to thoſe things which are neceſſary to be done for us.

§. 586. From hence we are enabled to underſtand the Reaſon of many Particulars relating to the Senſes, and which may be here propoſed as Queſtions; ſuch as,

1. Why corporeal *Signs* [1] having nothing more than the Will of the Creator, do in ſuch a particular manner, affect, direct, and change our Ideas?

2. Why it is impoſſible to *correct* [2] or to alter the ſecondary Imagination by any reaſoning, but only by Force or Violence?

3. Why *(cæteris paribus)* the external and internal Senſes are ſtronger, or more exquiſite, when the *voluntary Motions* [3] of the Muſcles ceaſe.

4. Why Attention, Memory, and Imagination ſtupify the *external* [4] Senſes, and ſup-

preſs the Motions of the Body? And why theſe Faculties lie neglected or at *reſt* [5] when the other Actions are vigorous?

5. Why the Body grows ſo very *weak* [6] when the internal Senſes are intenſely exerciſed for a long time?

6. Whence it is that the frequent *Change* [7] of the Objects or Subjects of Attention ſo much exhilarates the Mind?

7. Why *Meat* [8], Drink, Medicines, *Poiſons* [9], Reſt, *Exerciſe* [10], *Air* [11], Heat, Cold, *Cuſtom* [12], and *Paſſions* [13] of the Mind have ſo great an Influence in all theſe Reſpects?

8. Upon what State and Condition of the Body depends the *Judgment* [14] affirming or denying, with the *Reaſon* [15] and regular *Method* [16] of thinking? And laſtly, why *Diſtinction* [17] is of ſo much uſe towards right Reaſon? And why it ſo much oppreſſes the *Memory* [18] or ſecondary Imagination.

[1] Theſe ſigns are apparent in Speech and reading, for there is no affinity betwixt the Voice or Word, and the Idea of the Thing which we ſignify by that Word. If I pronounce the word Circle, every one immediately underſtands me, namely, an Idea is raiſed of a curve Line which I had in my mind when I pronounced the word Circle; but ſuppoſing a Foreigner to be preſent ignorant of my Language, he will hear the ſame Sound without underſtanding the Senſe, namely, without the Idea of a Circle following in his Mind. We learn to name our Letters when we are Children by a tedious and repeated Labour, and then to pronounce the Letters, whoſe force we have learnt,

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into Words, that is, to Read. Thus by degrees theſe Characters become familiar with us; ſo that there is a reciprocal and arbitrary Connection betwixt the Signs and the Sounds with our ſeveral Ideas, ſo that the common Ideas excited in the whole World may be related by us in Hiſtory, when at the ſame time there is no immediate relation either betwixt the Letters or the Sounds with the Things themſelves. But this is what has not been granted by God to Brutes; not even to Apes, which in other reſpects approach near to us. But this ſeemed to be a diabolical Invention to the *Indian* Slave, concerning whom I ſpoke at §. 570. *D. Ammannus*, my much regretted and ever to be lamented Friend, being moved with compaſſion towards a Country Lad who was born Deaf, and conſequently Dumb, taught him to hear with his Eyes by Signs, by which means the unfortunate Lad learnt to read and write in the ſpace of ſix Weeks time. He placed the Lad oppoſite to a Preacher who was explaining the ſacred Text, and the Lad fixing his Eyes upon the Mouth of the Preacher, took down the Sermon of which he had not heard a Word, ſo that he was able to repeat the ſame at Home. Yet he did not underſtand what had been ſaid; only he was taught by obſerving the Motion of the Face and Mouth in the Preacher, to move his own Organs in the ſame manner; and therefore what he repeated was only mere Imitation without Knowledge. Upon giving this Lad ſome Bread, he knew by experience in the Taſte what it was, and gave it the Name of Brood or Bread, when at the ſame time he was perfectly ignorant that he publiſhed any ſuch Sound, as we know we do when we pronounce the Letters of the word Brood or Bread. One who attentively conſiders theſe Particulars, will wonder at the

Connection

Connection of theſe Organs of the Senſes, one of which being affected alſo affects the other. A Lad who hears well will perceive in the Dark the determinate Voice of a Perſon producing any Tone, inſomuch that the Lad will imitate the like Sounds, and modulate his Voice to the ſame Tone. But who, I pray, now taught that Lad to make ſuch an infinite Number of the moſt complex muſcular Motions, by which conſpiring together the ſame Sound will be produced which he heard? But even this Faculty is not denied to Brutes, for the Parrot can do the ſame. If that Bird is ſuſpended in a dark and ſilent Place while young, and hears the Talk of but one Perſon, he will learn to imitate the Voice of him that ſpeaks. But how wonderful is this Connection of the Organ of Hearing with the Mouth and Organs of Speech, by which the latter are capable of publiſhing the ſame Sounds which are perceived by the Ears? But all theſe we perform by that wonderful and natural agreement which unites the external and the internal Senſes together: And by the ſame means we may explain, why black Points of a determinate Figure may excite the Love, Hatred, or Admiration of another Perſon; namely Becauſe determinate Ideas are connected by inſeparable Bonds to thoſe external Signs; ſo that when theſe Signs affect the external Senſes, they excite in the Memory and Mind thoſe Ideas which we judge them to repreſent.

[a] It is altogether impoſſible to overcome the ſecondary Imagination by the force of Reaſon only. Even the wiſeſt of Men often fall into the moſt falſe Notions, to which they ſo firmly adhere, that they cannot be ſeparated from thence, nor convinced of their Abſurdity by the moſt evident mathematical Demonſtration. Nor is this any wonder; for all the force of Reaſoning can never perſuade

perſuade me to believe contrary to the Evidence of my Senſes, ſo as to oblige me to think I do not ſee, when I ſee plainly with my Eyes. And this is a Law eternal and ſacred from the Creator. If *Pyrrhus* and *Sextus Empiricus* were to riſe out of their Graves and by the moſt ſubtle Reaſonings endeavour to perſuade me that I do not ſee, I ſhould certainly reſiſt them with Incredulity, and firmly adhere to my Senſes. For there is an eternal and inſeparable Connection betwixt the Impreſſion made on the common Senſory, and the Idea of the Mind ariſing from that Impreſſion. But as I believe my external Senſes, ſo I am obliged to confide in my Intellects. If a ſimilar and equally vivid Impreſſion ſhould ariſe in the common Senſory from an internal Cauſe in the ſame manner as is uſual from the Action of an external Object, the Mind is then obliged to confide as much in the Imagination, as it uſed to truſt to the Senſes. If my common Senſory is ſo diſpoſed as it was when I ſaw a red Circle before my Eyes, I ſhall then abſolutely believe that I ſee ſuch a red Circle. A melancholy Perſon of the moſt profound Reaſoning, and endowed with the trueſt Judgment in the nature of Things, will continue in the Opinion which the Mind conceived, until ſome violent motion in the Body makes a ſtronger Impreſſion upon the common Senſory than the internal cauſe of the preconceived Idea, and then he will be ſet free from his Prejudice. Many ſurpriſing Accounts of the Power of Imagination are given us by *Montaigne*, who by Inſtances proves that the wiſeſt of Perſons have ſome Objects in which they are delirious. I ſaw an eminent Gentleman who was perſuaded his Legs were two Straws; and though he was extremely well ſkilled in the nature of all other Things, he could not by

any

any Arguments be perſuaded from his Error: his Friends adviſed him to uſe his Eyes in the cleareſt Light, to handle his Legs with his Fingers, and convince himſelf of their retaining their natural Subſtance and Figure; yet he obſtinately perſiſted in his Opinion, being very tender and careful of his Straws, ſo that he would not ſtand upon them, leſt the brittle Supporters ſhould break. At length his Friends ſo much fatigued him by their Importunities, that they prevailed upon him to ſecure his Legs in ſtrong Boots that they might not be broke, and that when he had thus ſecured them to take a Journey into the Country in a Chariot to relax his Mind: but in the Way were placed two Students, who ſtanding up on one ſide of the Chariot maſked, and with their drawn Swords in the habit of Robbers, leaving the other ſide of the Chariot at liberty; the Gentleman perceiving this, forgot his Straw Legs, and betook himſelf to his Heels, jumping out very nimbly, and from that Time was cured of his Prejudice. From hence many thouſands have deplored the Weakneſs of human Knowledge, ſince this Gentleman as firmly believed that his Legs were Straws, both to his Sight and Touch, as he now believed that they were real Legs. A Counſellor at *Paris*, to whom the greateſt Affairs of the Law were uſually referred, retained his Urine from a fear that he ſhould drown the vaſt City, inſomuch that he would certainly have periſhed, unleſs the Phyſicians had found out a Device to undeceive him. They ordered an outcry to be made of a great Fire, which there was no hopes of extinguiſhing; hereupon the prejudiced Gentleman, to ſave the People, evacuated three or four Ounces of Urine, and at the ſame Time was freed from his Error. Another Perſon was perſuaded that he had the Snout

of

of an Elephant inſtead of a Noſe, and could not be brought to believe the contrary neither by his Senſes of feeling, and ſeeing himſelf in a Glaſs, nor yet by the Reaſonings and unanimous Teſtimony of By-ſtanders; at length a Surgeon made a ſmall Inciſion in his Noſe ſo as to ſet it on Bleeding, and eaſily perſuaded him that he had cut off the diſagreeable Snout. I knew another Gentleman of Letters who ſtrongly imagined that he carried about with him an uncommon Tumor, from which Prejudice he was freed by a ſmall wound in the Skin with the ſhew of a piece of raw Beef. In the cure of theſe People therefore care ſhould be taken not to oppoſe them in their prejudiced Opinion by reaſoning; for ſo ſtrong and familiar is the Idea ariſing from their Error, that you will never be able to convince them; but, on the contrary, they are to be humoured, and their Opinion corrected by ſome other Device oppoſite to their Delirium, which will not be otherwiſe curable. For ſo ſoon as you ſhall be able to excite a ſtronger Idea in the common Senſory, than that falſe one with which they are prejudiced, the equable diſtribution of Ideas is then reſtored, and with that the true Judgment of the Mind.

[3] If you walk with a Geometrician, and propoſe a difficult Propoſition to him by the way to be ſolved; he makes a ſort of Enquiry in his Brain, and you will perceive him ſtop continually at ſmall Intervals, and afterwards continue on in his Walk when he has reſolved the Problem. Thus all the other Paſſages to the common Senſory are ſhut up, that the one thing ſought for by the Mind may appear more diſtinct.

[4] A Perſon who is about to meditate or think upon any Matter, does not go into the *Exchange* or other publick Company, but retires into Soli-

tude,

tude, where there may be no ſenſible Objects to draw off his Mind, and where he may be free from all Motion; for by this means the Imagination will be the moſt quick or vivid, and the Memory moſt ready.

[5] The deep Study or Extaſy in which all the Parts are at reſt, is remarkable in the Inſtance of *Archimedes*. That great Geometrician drawed Cones, Spheres and Cylinders in Sand after the manner of the Philoſophers of his Age; in the mean time *Marcellus* ſuddenly overcame and diſperſed his Soldiers through the City, where they broke into the Muſeum of the *Roman* Philoſopher with their Swords drawn; but he not at all terrified at the Conqueſt of his Country, or the preſent Image of Deſtruction, commanded the Soldiers not to diſturb his Circles. The ſame *Archimedes* alſo, upon another Occaſion jumped naked out of the Bath, and run about in Public, being ſeized with a ſudden fit of Joy from his meeting with an Anſwer to a different Problem, which was propoſed to him by the King. This is a common Accident with melancholy People, who uſually apply their Thoughts and Senſes entirely to one Object, neither rejoicing, fearing, nor hardly thinking about other things.

[6] A Mathematician who has been labouring an Hour or two to ſolve a difficult Problem, will certainly be more wearied and fatigued than a Mechanic who has been working all Day. The Cauſe is, that in Meditation all the Paſſages from the common Senſory to the voluntary Motions are ſhut up, and the Spirits retained in the Brain, ſo that they cannot flow into the Muſcles; and therefore a long time is neceſſary to reſtore thoſe Motions, and to diſpoſe the animal Spirits into their equable Transflux to every Part; and from hence, rather than

than a Loſs of the Spirits, ariſes that Laſſitude. Meditating Men hardly perſpire, according to *Sanctorius*; and if they do perſpire, it is much leſs than in a Perſon exerciſed in walking, or any other mechanical Work.

[7] This Variation of Objects or Subjects upon which the Mind is employed, I muſt ſtrongly recommend to you and all who are ſtudious of Learning. The more ardent the Affection of the Mind is towards any Science, the more certainly will the Body be deſtroyed by Application to it, if you obſtinately fix your Study to that one thing. On the contrary, you may be able to ſpend a whole Life dedicated to the Muſes without fatigue, by mixing other agreeable Labours or Exerciſes with your Studies. We ought never to let our Minds be ſtrongly fixed for too long a time upon any one Subject, unleſs we would become melancholy; but we ought perpetually to alter our Thoughts upon various and oppoſite Subjects. A Geometrician perceiving any Languor approach, or Love of Solitude, always lays aſide his deep Meditations, and falls to Muſic or the reading of Poetry, which are Subjects of a very different Nature from mathematical Readings. Thus the common Senſory will labour equally in different Provinces, and be diverted by the Variety. But if you deſire to perſiſt in one Study, the leaſt Injury that can befal you will be an Incapacity towards the other Functions or Actions of human Life; and though it is certain that you will become learned, and may enlarge the Bounds of the Art to which you apply, yet take care that you do not become a Fool together with your Fellow Citizens.

[8] It gives me ſurpriſe to read the Writings and Diſcourſes of ſome wiſe Men, who think that their Thoughts depend upon themſelves; for even our

Food

Food only may ſuppreſs or obſcure that divine Part which is capable of this Faculty. A Geometrician who before Dinner is capable of reſolving a moſt difficult Queſtion, becomes dull, ſleepy, and ſtupid by a large Meal, and the more ſo if he has drank freely; ſince fermented or ſpirituous Liquors have the ſame Effect. It is not poſſible for the Thoughts of a Perſon to be the ſame when he is drunk as when he is ſober; and the Ancients have long ago pronounced, that one who drinks Wine will think differently from one who lives contentedly with Water. Even the moſt wiſe *Socrates* was for dancing at the Feaſt of his Scholar *Xenophon*, when he ſaw a moſt ſkilful Harlequin; but, ſays *Cicero*, no one danced more ſoberly or gravely.

[9] There are ſome Poiſons diſcoverable by Experiment, and which have been ſo improved by the horrid Art of thoſe who have been employed as Poiſoners, that any Paſſion or Faculty of the Mind may be ſuppreſſed by its reſpective Poiſon, and others excited by ſome proper Remedy. We are not to look upon the Writings of the Ancients as mere Fables, when we read their Accounts of Philtres. In the Empire of *Indoſtan*, it is a Practice at Court to quell Seditions by a Drink which the Subjects of the *Mogul* call Pouſt, made by an Infuſion of Opium with the Stramonium: A Portion of this Medicine is ſwallowed by thoſe who are at the Head of the Conſpiracy, without which they are not to have any Dinner; and thus the Body is indeed not much changed only a little emaciated; but thus the Principle of our Humanity is ſuffocated: For the Senſes, Perception, Memory, Judgment, and other Faculties of the Mind are gradually effaced, leaving the Body to live as it were a mere vegetable Life, if that may be called living.

living. So ingenious has wicked Ambition made Mankind towards their own Deſtruction; namely, for fear of a ſeditious Revolution in the Empire, the new made Emperor uſually kills all his younger Brothers, preſerving his own Offſpring only: but even then he is not ſafe, for afterwards Princes are produced who are ſaid to have eſcaped that Fate. But they who proceed with a more cautious Ambition, ſpare the regal Blood of their Kindred and keep them living; but ſo ſtupify or infatuate them by the forementioned poiſonous Drink, that if any ſtrong Faction or Tumult is raiſed, the living Image of a Man is produced to the People, deſtitute of all Power of thinking.

[10] One who is reaſoning cannot walk, but is obliged to ſit or ſtand ſtill, unleſs he will run the Hazard of falling into Error.

[11] The State of the Air has evidently a conſiderable Influence upon the Faculties of the Mind, according to the different Seaſons of the Year, intenſe Heat or Cold, *&c.*

[12] Nor is Cuſtom or Uſe often of leſs Force.

[13] Theſe Affections ariſe from a greater Impreſſion made upon the common Senſory; and which therefore conſequently diſturb the Thoughts and Uſe of our Reaſon.

[14] I do not here aſk what Judgment is, to avoid running into a metaphyſical Queſtion; but I only enquire what Condition of the Body that is from whence Judgment reſults. By Judgment, I intend the Formation and Perception of two Ideas at once in the Mind, which makes an Enquiry whether they are the ſame or different. I aſk then whether a Triangle and Circle are of the ſame Figure? to which every one will anſwer in the negative; and add, becauſe the Idea or Mode of a Triangle is perceived different from that of a Circle. From

hence I conclude, that Judgment is not an Action of the Will aſſerting or denying, as it is defined by *Carteſius*. For no Perſon in his right Mind will ſay, that two and three make four; or even if he was to ſay ſo, it would not be believed by himſelf. For Judgment is the real Difference betwixt the Similitude or Diverſity of Ideas which are raiſed at the ſame time in the Mind, and is therefore not a Conſequence of any Part in ourſelves, but of the mere Ideas only; ſo that the ſame Difference or Similitude will oblige the Mind to judge whether it will or no, that one is one and two are two when the ſame Numbers are preſent. Perception only determines the Judgment, which will be juſt when both Ideas appear equally diſtinct and clear; but wrong when you perſuade yourſelf, that two Ideas are one and the ſame before they have been diſtinctly repreſented. Attention is the only means to rectify this Error, not from its changing the Thoughts but from rendering the Ideas more diſtinct, namely, by giving a ſtronger Repreſentation of the thing itſelf, ſo that it may be more vivid in the common Senſory at that time than any other Impreſſion. Attention is therefore neceſſary to form a right Judgment, ſince that alone renders the Ideas diſtinct: By Reaſon we underſtand the Compariſon of Judgments, as Judgment is the Compariſon of Ideas. After you have ſeen that 5^2 and $4^2 + 3^2$ make likewiſe 25, and then conclude there are therefore $5^2 = 4^2 + 3^2$; then this Concluſion is Reaſon. But for Reaſon to be juſt, the two Ideas ought to be clearly perceived in the Mind; and then the third Idea, with which they are compared, ought likewiſe to be equally clear; and then we may be capable of concluding in the affirmative or negative without Error, concerning the Agreement or Difference of

thoſe

thoſe Ideas: and therefore reaſoning appears to be a Complication of Judgment; and conſequently it requires more time than ſimple Judgment. Hence it is that we find ſome Men of bad Memory who judge well but reaſon worſe. Fools clearly perceive and judge alſo diſtinctly, but they reaſon wrong; for that requires a Continuation of many Ideas, which ought to be obſerved at one and the ſame time in the Mind, and in this they err.

[15] This is the moſt perfect in the mathematical Method or Order, that is, when the Principles to be learnt are diſpoſed in ſuch Order, that no Idea is aſſumed but what has been firſt expreſſed before by a clear and adequate Definition; but a thing can be well defined only when it is clearly perceived. Moreover, from theſe Definitions are deduced moſt ſimple Combinations, concerning which there is not the leaſt room to doubt; and then theſe Definitions and primary Combinations having been ſtrictly examined, are aſſumed as Fundamentals or Principles from whence more obſcure and complex Propoſitions are deduced, which yet contain nothing which is not certain or evident in the preceding. When a Geometrician once in his Life is obliged to believe even againſt his Inclination, that three Angles of any Triangle are equal to two right Angles, he will always believe it and eſteem it as an indubitable Axiom as long as he lives. *Euclid* has given us a notable Inſtance in his fifteen Books, of the manner in which we may proceed juſtly, from the moſt ſimple Propoſition to the Demonſtration of the moſt intricate Theorems.

[16] A Perſon will not be in danger of Error who does not confound any two ſimple Ideas. He will become a good Anatomiſt who conſiders, that an Artery is of the ſame Nature in every Part of the Body, but that all the Actions of the Body reſult from

the Action of the Artery; which he therefore conſiders by itſelf as a ſimple Propoſition, remarking, remembering, and digeſting its ſeveral Properties, and then uſing its ſeveral known Properties to explain the whole animal Œconomy.

[17] & [18] Judgment and Reaſoning are repugnant to, or refuſe a geometrical Method, becauſe it ſubjects us to one moſt conſiderable Impreſſion, namely, a ſingle Notion of a complex Idea; ſince the Imagination cannot retain all Notions at once. Paſſions of the Mind likewiſe act in the ſame manner; for theſe occaſion the Ideas to be repreſented to us otherwiſe than they are without us, combining them with ſome of the ſtrongeſt Affections in the common Senſory. The Ideas therefore of things are very much altered, according as they are either accompanied with Love, Hatred, or Admiration.

Of Vigilance *or* Watching.

§. 587. A PERSON is ſaid to be *awake*[1] or watching, whoſe external and internal Organs of Senſe with the Inſtruments of voluntary Motion, are ſo diſpoſed that they can eaſily exerciſe their accuſtomed Offices or Motions, and be readily affected by Objects.

[1] Thus we call that State of the Body, in which the Actions of the internal and external Senſes and Motions of all the Muſcles may be readily or nimbly performed without any Reſiſtance. I am awake when my Eyes being open continually ſee all Objects, but when I am aſleep my Eyes are inſenſible: I am

I am awake alſo when I perceive the leaſt audible Sounds, and when thoſe Sounds eſcape me I am ſleeping. I am awake when by the leaſt Inclination of the Mind or Determination of ſome external Object my Muſcles move, my Tongue ſpeaks, and Feet walk, *&c.* I am therefore awake ſo long as that phyſical Condition continues in the common Senſory, by which the Actions of external Objects being applied in the uſual manner to the Organs of the Body, excite the reſpective Ideas in the Mind. I am alſo watching when the leaſt Change in the thinking Principle may determine the Principle of Motion towards the Muſcles, though the Motion or Act itſelf cannot be determined. It is provided by a wonderful Inſtitution of the Creator, that one half of our Lives we ſhould be Machines, and the other half cogitative or thinking Beings.

§. 588. Vigilance therefore altogether depends upon the *Preſence* [1] of a large Quantity of laudable Spirits in the Brain and its Medulla, with the Nerves and Muſcles; and alſo upon the good Condition of the ſolid Parts conſtituting the Brain, Nerves, and Muſcles.

[1] That is, when Spirits are duly ſecerned in the common Senſory, or in the whole Origin of the Medulla from the cortical Part of the Brain, where, after their Separation from the arterial Humours in the Cortex, the ſecerned Spirits are ſent into the Beginning of the hollow medullary Fibres, which are thus equally filled, and through them may be equally conveyed to the five external Organs of Senſe, and to the voluntary Muſcles. Vigilance therefore in the human Body conſiſts in an equable Repletion in all the Nerves which ariſe from the Brain.

§. 589. Vigilance may be therefore ſaid to be that State of the Body, in which the Circumſtances of the two preceding Sections concur.

Of Sleep.

§. 590. BUT the Knowledge of Sleep was always eſtemed to be much more obſcure, even though it be only the *oppoſite* [1] State to *Vigilance* [2] or Waking; and therefore to acquire a Knowledge of its Nature, it is neceſſary for us to conſider accurately, all the *Phænomena* [3] or Appearances with which Sleep is attended; and ſuch are the following:

1. A Perſon who begins from waking to fall into a Sleep, gradually grows dull, while at the ſame time all the Senſes both *external* [4] and internal are more difficultly exerciſed, and being accompanied with a Weight or Heavineſs of the whole Body, they at laſt altogether ceaſe.

2. All the *voluntary* [5] Motions *begin* [6] to be retarded by degrees, and afterwards diminiſhed with the Senſe of a great Reſiſtance, and at length wholly ceaſe.

3. The Muſcles deſtined to perform thoſe voluntary Actions grow *flaccid* [7], collapſe, become looſe and in a manner paralytic, firſt in the *Eye-lids* [8], and then in the *Face* [9], *Neck* [10], *Arms*,

Arms [11], and from thence downward, deſcending *gradually* [12] through all the lower Limbs.

4. All thoſe corporeal Actions and Paſſions of the Mind *ceaſe* [13], which follow as Conſequences of the other three.

5. But in the mean time the Motion of the Arteries, Veins and Heart become *ſtronger* [14], *ſlower* [14], move equable and full, paſſing through different degrees of *increaſe* [15] according as Sleep itſelf increaſes.

6. The Reſpiration becomes *deeper* [16], ſtronger, ſlower, and more equable by degrees, increaſing in proportion as Sleep itſelf advances.

7. And therefore all the Actions which depend upon theſe two (§. 5. and 6.) are more *perfectly* [17] performed; and therefore the Circulation of the Blood is better carried on in order to a due Concoction, *Secretion* [18], *Perſpiration* [19] and *Diſtribution* [20] of the Humours with the *Nutrition* [21] of the ſolid Parts; aud more eſpecially the Motion of the Humours is *accelerated* [22] through the Blood-veſſels which are nearer to the Heart, but ſlower through the lateral Veſſels, and thoſe which are more remote from the Heart, towards which in the time of waking they are propelled by the Contraction of the voluntary Muſcles.

8. A Perſon ſleeping *awakes* [23] when any external Object *violently* [24] affects the Senſory; or from the Senſation of ſome *Uneaſineſs* [25]

from the Stimulus of any Excrement, or from the Uneaſineſs ariſing from the Compreſſure of any Part, which has been lain upon too long; but ſometimes the Perſon awakes *ſpontaneouſly* [26]. Laſtly, the longer Sleep is continued, ſo much the more is *Sleepineſs* [27] increaſed, ſo that (*cæteris paribus*) at length almoſt the whole Life may be ſpent in Sleeping.

9. When a Perſon awakes, he ſeems to be at firſt as it were *convulſed* [28], the *Eye-lids* [29] are next opened, the Limbs *ſtretched* [30], the Perſon gapes or yawns, looks *drowſy* [31], but by degrees becomes fit for Senſe and Motion; and then finding his Strength renewed, he is in full Vigour.

[1] Vigilance is when the Body is eaſily affected by external Objects capable of tranſmitting their Impreſſions to the Mind; and, on the other hand, when the Mind by the Will eaſily influences the Body. On the contrary, Sleep is that State in which no Idea is tranſmitted from without to the Mind, and the Mind itſelf exerciſes little or no influence upon the Body. That is to ſay, the Creator, who has preſcribed Laws to the human Species, as well as to other Animals, has placed in our Bodies, as well as in Brutes, a twofold Machine, one of which continues to act until the whole is deſtroyed; that is to ſay, 1. The Heart and Organs of Reſpiration ſo far as theſe laſt conduce to Life; to which add the periſtaltic Motion of the Inteſtines, and all thoſe Motions which derive their origin from the Syſtole and Diaſtole of the Heart. When theſe Machines are at reſt, the Body is perfectly dead, ſo that it can never be raiſed again in this World. The other Machine in the Body is the animal Part, which

which acts and rests alternately at times. By reason of this viciſſitude in the animal Part it is that Man is no more than a mere Machine during a conſiderable portion of his Life, namely, in the time of Sleep, at which time the animal Part is dead, and the former vital Machine only continues to act; but if that alſo ceaſes, a fatal Sleep enſues, from which we never awake, namely, perfect Death itſelf. Theſe two kinds of Death are wiſely called Siſters by *Homer*, and by *Gorgias Leontinus* the Orator; for Sleep and Death differ only as to Time or Extenſion. Sleep is the Death of the Brain continuing for a ſhort time, while in the Interim the Cerebellum continues vigilant and active; but when the Cerebellum alſo ſleeps, or ceaſes from Action, it produces a perfect Death of the whole Animal.

[2] This is a ſtate of the common Senſory, in which, with reſpect to the Solids, the Nerves in their Origin readily receive their ſpirituous Fluid or Juice, and eaſily permit the ſame to paſs through. But with reſpect to the Fluid itſelf, Vigilance may be ſaid to conſiſt in a ready and plentiful Flux of the Nervous Juice ſecerned from the Blood of the carotide and vertebral Arteries, ſent into the Origin of the Medulla and Nerves ſo plentifully and freely, as to be moſt fit for Motion, to be eaſily determined according to the Variety of external and internal Impreſſions. On the other hand, Sleep with reſpect to the Solids conſiſts in a Compreſſion or collapſing of the ſmaller Veſſels of the Brain, ſo that they are not able to tranſmit their Juices; but with reſpect to the Fluids, Sleep follows when the Matter or Humours forming Spirits do not flow to the cortical Part of the Brain, or when the ſame Spirits are not there ſeparated, or elſe when they are not continually ſent into the beginning of the Medulla. I have

[3] I have frequently ſpent whole Hours in obſerving the appearances of Sleep in Children and innocent People, and have by that means accurately remarked all the Changes by which they fall into a Sleep from being awake.

[4] A Perſon who is ſleepy, but not yet fallen into a Sleep, has his Hearing, Sight, and other Senſes more dull, next the Attention ceaſes; afterwards the Memory and other Paſſions of the Mind become weak, the Thoughts and reaſoning are interrupted or confuſed from what they were before; ſo that the Ideas are confuſed, and by degrees their Connection broke.

[5] The firſt degree of Sleep beginning is, that we yet remain conſcious that we are going to Sleep; for Sleep itſelf, as ſome of the Antients have well obſerved, takes hold of thoſe who fly from it, and flies from thoſe who follow it; for no Perſon ever obſerved in himſelf in what manner he began to ſleep.

[6] People think they are doing nothing when they ſit ſtill, when at the ſame time they labour incredibly hard. But this Opinion ariſes from uſe. Muſicians who have nothing more before them than ſixteen Notes or Marks upon the Lines of Muſic, are by them only determined to each Key; after which their expert Fingers move with ſo great a Velocity that they do not miſtake one Note, nor yet do they know that they agitate ſuch an infinite number of Muſcles. For all the Muſcles of the Back, namely, the Sacrolumbales longiſſimi, Semiſpinales, and others of the like kind, are employed in erecting the Body. Nor is the Head ſuſtained but by the Action of many Muſcles, which ceaſing at the time of Sleep, the Head inclines forward. The ſame is alſo true with reſpect to the lower Jaw. Therefore the ſecond degree of Sleep

is

is an inſuperable Reſiſtance of the Muſcles, which obſtinately refuſe to continue their Action; ſo that the Eye-lid, for inſtance, cannot be ſuſtained by the ſtrongeſt influence of the Will, though in the Time of waking it was moved without the leaſt Senſe; alſo the weight of the Head and lower Jaw ſeems great to a Perſon who is inclined to Sleep, though it be not at all perceived at the time of Vigilance. In Sleep therefore the animal Spirits ſeem to be rendered unfit for Motion in the common Senſory.

[7] They become flaccid, paralytic, or immoveable; in which they differ from a Cramp or Tetanos which is joined with a Rigidity. Such a flaccidity of the Muſcles is a moſt certain ſign of Sleep.

[8] This is a wonderful providence, ſince no part of the Body is more in danger during Sleep than the Eye, which is required to be perfectly clear and tranſparent. Nature has therefore placed a ſafe guard to the Eye-lids, namely, an orbicular Muſcle, and has ſo formed the Eye that we cannot be able to go to Sleep till the Lids are cloſed. And therefore not all the Muſcles in the Body are relaxed at the time of Sleep; for the Sphincters then act the moſt ſtrongly, that is to ſay, the Sphincters of the Eye-lids, Mouth, Bladder, and Rectum are contracted in the time of Sleep.

[9] Infants inclining to Sleep, begin firſt to nod, the Muſcles of their Face become lax or plain, the Lips and Cheeks ſubſide as in Death, and the lower Jaw falls down; and from theſe ſigns only one may eaſily know that a Man is inclining to Sleep.

[10] I have frequently obſerved People falling aſleep in ſome public Place, as for inſtance, at Church, where the Eyes firſt wink, and then the Head

Head nods; at which awaking, they riſe up a little amazed, and hold their Head ſteady; but it is not long before they let it ſlip again, Sleep ſtealing on ſo that the Muſcles cannot ſuſtain the Head, becauſe they are relaxed; but all of them are not relaxed at once, becauſe the Head inclines this way or that according as the Muſcles on this or the other ſide happened to be leſs paralytic than the reſt, ſo as to draw the Head to their ſide. Nor is it long before the Muſcles of the Neck are alſo relaxed, whence the Head is inclined forward; and this is a Stage differing from the former. Nor is the Will capable of reſiſting the force of Sleep, as Soldiers know by ſad experience when they are not capable of ſhaking off Sleep while the Enemy watchfully ſurrounds them, even tho' they know that they purchaſe this pleaſure at the expence of their Life. All this irreſiſtible Power of Sleep is very well expreſſed by *Virgil:*

Jamque fere mediam cæli vox humida metam
Contigerat, placida laxarant membra quiete
Sub remis fuſi dura per ſedilia, nautæ;
Cum levis ætheriis delapſus ſomnus ab aſtris
Aera dimovit tenebroſum & diſpulit umbras,
——— ——— — fuditque has ore loquelas:
Aquatæ ſpirant auræ, datur hora quieti;
Pone caput, feſtoſque oculos furare labori.
Ecce Deus ramum, Lethaeo rore madentem,
Vique ſoporatum ſtygia ſuper utraque quaſſat
Tempora: cunctantique natantia lumina ſolvit.
Vix primos inopina quies laxaverat artus,
Et ſuper incumbens, cum puppis parte revulſa,
Cumque gubernaclo, liquidas projecit in undas
Præcipitem, ac ſocios nequidquam ſæpe vocantem.

So

[11] So that no one can ſleep with their Body erect, for the Column of the Spina dorſi is held ſtrait by the conjunct Action of an infinite number of Muſcles, the power of which being abſent, the whole Trunk collapſes. And ſoon after, if ſuch a Perſon who is about ſleeping endeavours to ſtand upright, he will accordingly tumble down upon the Floor.

[12] They who write while they are awake, as they fall aſleep perceive the Pen ſlipping out of their Hand. Cranes are ſaid to keep a watch to guard againſt any Alarm, that is, one of the Flock ſtands upon one Leg holding a Stone in the other, ſo that the Stone falls and keeps the Watch-bird awake ſo ſoon as he begins to ſleep. When the Muſcles act they are hard and turgid; and ſuch will be the ſtate of the Muſcles of the Hand, while it graſps a Stone; but thoſe Muſcles grow flaccid and ſoft, when the Perſon is about to ſleep and let the Stone fall.

[13] This State of the Brain is the ſame as in the Man at *Paris* mentioned before (§. 284.) who had his Dura Mater naked; for when any one giving a Stipend compreſſed the Brain of this Man, he began to grow ſleepy, inſomuch that the Sleep became profound when the Preſſure was gradually increaſed. But here we ſpeak of that perfect Sleep which is the Image of Death, in which therefore there is cauſe impeding the Spirits from flowing into the Nerves, whether that be a conſequence of a Paucity of Spirits, a Stagnation of them, or an Inaptitude to Motion.

[14] For the ſtrength of the Pulſe increaſes in Sleep, though it becomes ſlower in number: for if you count the Number of Pulſes in a Child while waking, and compare that number with the Pulſes made in the like ſpace of time during Sleep, they

they will be found fewer in Sleep, but more equable, full and ſtrong; and from this ſign only you may know that a Child is ſleeping in the Cradle, even though you uſe no other Senſe. In a Phrenzy, when a Patient begins to incline to Sleep, one may be able to judge of the Force of the diſorder by the Pulſe; for when the Pulſe is larger, ſtronger and ſlower than in the time of waking, the Sleep will be ſerviceable; but if the Pulſe is quicker and weaker, the Sleep will be but ſhort and of no ſervice.

15 The moſt profound Sleep is a perfect Apoplexy, in which the Pulſe is uſually exceeding ſtrong, inſomuch that the Vital Powers appear ſtronger a little before Death in an apoplectic Patient, than they were ever obſerved in the ſame Perſon in Health. At the ſame time they are hot, look red, and ſweat all over, the more as the Sleep is profounder. In an Apoplexy therefore, and in Sleep, the Force of the Heart, Arteries and Veins is increaſed.

16 A ſleepy Perſon may be eaſily known from the manner of his breathing; for he breathes more deep and ſlow with a kind of audible Sound; whereas we do not hear the breathing of a Perſon who is awake, as we do in Sleep from the ſtrong Depreſſion of the Diaphragm and Elevation of the Ribs. Hence in Sleep the Perſpiration ſeems to be moſt perfectly carried on; but when the ſame is increaſed, it becomes audible, and produces a kind of Snoring like that which the Bronchia yield in a fatal Apoplexy, and which is a certain ſign of Death. But even a moſt profound Sleep is nearly related to an Apoplexy.

17 All the vital Functions are ſtronger in a Perſon who is ſleeping, and are more perfectly exerciſed, namely, the Concoction of the Stomach, the periſtaltic

periſtaltic Motion of the Inteſtines, the Secretion of the inteſtinal Juice, of the Bile and pancreatic Juice, with Alterations of the Blood in the Lungs, Heart and Arteries, the ſeveral Secretions and Aſſimilations, which are all better performed in Sleep than in Vigilance. All the Veſſels are therefore well diſpoſed, except thoſe which are ſubſervient to the animal Faculties and Functions, while thoſe which depend upon the Equability of the Circulation are better performed in Sleep, excepting the Functions of the Brain and Nerves.

[18] The Separation of one Liquor from another, and the Secretion of diſſimilar Parts from the homogeneous Blood.

[19] When the Humours are moſt equably diſtributed and applied to all the Veſſels in the human Body.

[20] This Diſtribution proceeds from the Arteries, whoſe Motion depends always upon the equable Force of the Heart; but the Equability of that Force is often interrupted by the Muſcles; and therefore it becomes more agreeable when they are at Reſt.

[21] Nutrition firſt requires a Preparation of the nutritious Matter, and afterwards a Diſtribution of it when prepared, that it might be applied to the ſolid Parts and firmly adhere to them. All theſe Circumſtances are beſt executed in time of ſleep, which therefore reſtores the Limbs which had been fatigued with daily Labour.

[22] In a Perſon who is ſleeping many Actions ceaſe, and yet the greateſt Heat is diffuſed throughout the Body; for every Perſon is warm while ſleeping, even though they were cold when they firſt compoſed themſelves to ſleep. But yet I do not affirm that all the Humours are moved more ſtrongly than in the time of Vigilance; but I here

ſpeak

ſpeak with regard to the Veſſels and Humours of the firſt kind, and of the Motion of the latter into the ſmall lateral Veſſels. But with reſpect to the Humours which are transferred from the Arteries into the Veins, they are accumulated in theſe laſt, and not urged forward by the Action of any of the Muſcles towards the Heart. Hence the Body is by Reſt filled with Humours ſtagnating in their Veſſels. In a word, the Motion of the Humours in the firſt Series of Veſſels, that is, in the ſanguiferous Arteries and Veins, with their Appendages, the Sinus's and Auricles, is more accelerated during the time of Sleep than Vigilance; but in the ſerous Veſſels, the Lymphatics and Nerves, the Circulation is little or nothing at that time. But the Heat of the Body is increaſed by the Attrition of the Humours augmented in the large Veſſels; for this Attrition is the ſole Cauſe of animal Heat; and the Heat of the Body is diminiſhed in proportion to the Loſs or Conſumption of the red Blood. Hence therefore the Blood only is accelerated during the time of Sleep, while the reſt of the Humours circulate more ſlowly than when a Perſon is awake.

[23] A Perſon awakes by a Commotion excited in the common Senſory, which was before at reſt; whether that Commotion is excited by an external or an internal Cauſe.

[24] When an intenſe Light illuminates the Eye, or when a great Noiſe affects the Ear, or the like Impreſſion powerfully moves our Senſes. Sleep therefore terminates when the external Senſes begin to perform their proper Offices; and this happens when the external Nerves are powerfully irritated by the Objects, and by that means ſtrongly preſs back the Spirits in the Nerves towards the common Senſory.

The

25 The general Cauſe of our awaking is that ſome Part of the Body, (for Inſtance, the Back or Side which has been lain upon for ſix Hours) is half inflamed, from whence an uneaſy Senſe ariſes. Otherwiſe the Stimulus of diſcharging the inteſtinal Fæces, or evacuating the Bladder, or elſe of ſpitting freely to clear the Lungs, or by a ſneezing which expels the Humours of the Noſtrils.

26 It is commonly believed that we awake naturally only from Cuſtom or Uſe, becauſe the Spirits are recruited within a definite time, ſo as to diſtend the nervous Tubes. But I much doubt whether the Mind ever awakes ſpontaneouſly of itſelf; I ſay ſpontaneouſly, while the Mind continues in the ſame Diſpoſition in the Body as it was while aſleep, the Sleep ending without any new Action excited in the Mind; and therefore I doubt whether a Perſon awakes merely from the renewed Quantity of Spirits without any external Cauſe or other Stimulus. I have made ſome ſurpriſing Experiments with regard to this both in myſelf and in other Animals. The more a Perſon ſleeps, the greater is the Inclination to ſleeping. One who ſleeps but a ſingle Hour beyond his uſual time, will be ſleepy all that Day. A very rich Youth who went from *Leyden* to take up his Title of Nobility, having over-drank himſelf, was ordered by the Prince to be carried from the reſt of the Courtiers into a ſilent and dark Place, where he ſlept three Days and three Nights; for whenever he awoke, believing it to be the middle of the Night, he returned to ſleep again. I ſaw a certain Phyſician of ſome Learning, who took a wonderful Delight in ſleeping: he by retiring into a dark and ſilent Place ſlept ſo perpetually, that having loſt his Intellects, he periſhed ſtupid in an Hoſpital. This unfortunate Gentleman was captivated with an

Opinion that Sleep was uſeful to him, and therefore paſſed many Days in Sleep; but when he was awaked the firſt time by his Friends, it was evident he had loſt much of his Learning; and by repeating again his profuſe Sleeping, he became at length quite ſtupid.

27 Namely, an Animal placed in a dark Room where there is no Light nor the leaſt Noiſe, has been obſerved to ſleep perpetually. Many Animals ſleep the whole Winter. Weaſels of various kinds, Foxes and Beavers betake themſelves to Sleep at the Approach of the Winter's Cold; and thus they continue till they awake in the Spring. Many Particulars have been collected by *Fortunius Licetus* with regard to this, in his Treatiſe of Animals which live a long time without Food or Air. Dogs well fed and uſing no Exerciſe, ſleep quietly almoſt Day and Night.

28 A Dog or any Perſon of our own Species being ſuddenly awaked, is always in a manner convulſed by the ſudden Influx of the Spirits into the Muſcles, which continue relaxed during the whole time of Sleep; by which means they are ſuddenly obliged to contract.

29 As the Eye-lids are the firſt which collapſe or become paralytic, ſo are they the firſt of the Organs which are excited or moved upon waking.

30 Not only Man but the moſt active Animals, ſuch as the Lion, Tyger, and Leopard who ſleep in Dens, ſtretch all their Limbs as ſoon they awake, and then recover their former Strength. By this means the Spirits ſeem to be reſtored to their free and equable Courſe through the Nerves of the Limbs.

31 The Vigour of the Senſes does not return altogether and at once; for even the ſtrongeſt Animals are much weaker by long watching, and may be

be eaſily overpowered in their firſt Endeavours to riſe up from Sleep. —— From this whole Hiſtory it is evident, that to recover a Perſon from Sleep to Vigilance, it is neceſſary for that Impreſſion which is conveyed through the ſenſitive and motive Nerves to paſs to the Senſory, and reſtore the Vigour of the voluntary Muſcles, and remove Sleep. Sleep is therefore a Reſt of the animal Faculties, or of the Inſtruments belonging to Senſe and Motion.

§. 591. Sleep is occaſioned, promoted, and increaſed in us,

1. By Eating two plentifully of the more *ſolid*[1] tough Aliments, which remain a long time in the Stomach.

2. By Drinking plentifully of vegetable fermented Liquors, which are the more ſomniferous in proportion as they abound with inflammable *Spirits*[2].

3. By the Uſe of *Spices*[3], which are very penetrating, fragrant and ſpirituous; to which add Saffron, *Clary*[4], Sage, and the like, which yet are free from any injurious Acrimony.

4. By the milky Juice of Poppies, the viſcid Juice of Hounds-tongue, and the Juice of wild *Lettuce*[5], *Mandrake-apples*[6], or the Juice of *Nightſhade*[7].

5. By *Wearineſs*[8] from violent Labour ſuſtained for a long time.

6. By a moſt *quiet*[9] Diſpoſition of Mind, while at the ſame time the Body is perfectly at reſt, and unaffected by the Action of any ſenſible Object.

7. By Exceſs of *Heat* [10] or *Cold* [11] too much increaſed, whether proceeding from ſome common Cauſe, or from the particular Temperature or *Age* [12] of the Perſon.

8. By all ſuch Cauſes as hinder the *Protruſion* [13] of the vital Blood into the cortical Part of the Brain, impede the Courſe of the ſame through its Veſſels in that Part, and conſequently obſtruct the neceſſary *Secretion* [14] of the Spirits thence depending, with the Derivation of them into the Nerves, Organs of Senſe, and voluntary Muſcles; and alſo impeding the *Return* [15] of thoſe Spirits from theſe ſeveral Parts towards the common Senſory: hence it may be from too profuſe *Evacuations* [16], a *phlegmatic* [17] Diſpoſition of the Humours, or too much *Fat* [18] urging the Humours inward, a Plethora compreſſing the ſmalleſt Veſſels, *Wounds* [19] of the Brain, an *Inflammation* [20] of it or Abſceſs there formed, an Extravaſation of Humours under the Cranium of the Brain, a *Compreſſure* [21] thereof, the *Loſs of Subſtance* [22], a Putrefaction; and many Accidents of the like nature, which if they do not injure the *Cerebellum* [23], produce Sleepineſs and Stupidity without interrupting the vital Functions.

[1] If the Stomach is filled with Fleſh-broth, you will not ſleep; but if inſtead of that it is filled with Beef, it will render a Perſon perfectly ſleepy. And this is ſaid to ariſe from the Preſſure of the diſtended Stomach upon the deſcending Aorta; but it may poſſibly be from the Aliments more ſtrongly affecting the nervous Papillæ of that Organ, ſo as to cauſe a Derivation of the Blood or Spirits

Spirits from the Head or animal Organs towards the natural or chylopoietic Viſcera; whence the former will be weak, and the latter more ſtrong and inclined to Action.

2 Among all things which excite a fatal Sleepineſs, that may be moſt certainly produced by Spirit of Wine, which if drank in too large a Quantity, produces ſudden Death, as I once obſerved in this City in a Man who made Experiment how much he could bear, but in ſix Hours time was taken off with an Apoplexy. There is not any kind of Drink which inebriates, but in proportion to the Quantity of inflammable Spirit which it contains; and the ſooner do Liquors fuddle, as they contain more of this Spirit. But the greateſt Degree of Drunkenneſs always produces a moſt profound Sleep, a Snoring, and an Apoplexy itſelf. Thus *Hippocrates* has formerly obſerved, in the fifth Aphoriſm of his fifth Section, that thoſe who loſe their Speech and lie without Motion in Drunkenneſs, die of an Apoplexy within three Days time, unleſs they recover their Voice within that Space, in which a Crapſula uſually terminates; namely, within twenty-four Hours, or elſe they will be taken with a Fever.

3 Among the Effects of Spices the moſt conſiderable is a Pungency and Bitterneſs, by which they heat the Tongue. But there is ſcarce any of them more bitter and warm than the pureſt Opium which has been lately brought in Tears from *Ægypt*, which is the true Juice diſtilling from Inciſions in the Poppy-heads, ſo greatly in requeſt by almoſt all the *Eaſtern* Nations or *Aſiatics*, and ſo ſharp upon the Tongue that it excites almoſt an intolerable Heat; and being applied to the Skin like a Plaiſter raiſes a Bliſter. This warm or ſpicy Opium therefore and ſuch like Subſtances excite Sleep. I have been told by Druggiſts and Gro-

cers, that when they have received large Parcels of ſtrong Aromatics lately arrived from *Aſia*, ſuch as Camphire, Saffron, or the like, that upon ſuddenly opening them both themſelves and Servants have been invaded with an almoſt inſuperable Sleepineſs. When new Wines are racked off from one Caſk into the other in a Vault, all the Workmen become ſleepy, merely from the Vapours. There are therefore different Cauſes of Sleep, beſides thoſe which are commonly known; for theſe ſpirituous Subſtances all excite Sleepineſs.

[4] A Perſon will be ſleepy after walking amongſt Clary; and the ſame will be alſo found true after walking amongſt Bean-flowers; in ſhort, a Perſon who takes a Nap in the midſt of a Bean-field will become ſtupid.

[5] Namely, the wild Lettuce, having the virulent Smell of Opium, according to *Bauhine (odore opii viroſo, X. B.)*. We read that Botaniſts have obſerved that People have been killed by eating Lettuce in the hot Seaſon of the Year in *Italy*. But this fatal Conſequence does not ariſe from the common Lettuce of our Gardens, but from that *Italian* ſort, which being broke tranſudes a Juice like Milk, white, and ſmelling ſtrong like the Juice of Poppies; and which Juice being taken in great Quantities, together with the Plant itſelf, produces exactly the ſame Effects with Opium.

[6] There are many who deny Mandrake-apples to have this Power, and there are ſome who have ſwallowed thoſe Apples publickly; yet the generality of Writers enumerate them among the Tribe of Narcotics. However, a certain Profeſſor at *Paris* eat one of thoſe Apples in the public Chair without any Detriment.

[7] More eſpecially the Solanum or Nightſhade of the Shops.

From

[8] From Wearineſs follows the moſt profound Sleep, even much reſembling Death itſelf. I have known ſome ſo much fatigued with Labour and long Watching, that they have fallen aſleep by the Sides of Mortars, from whence they fling Bombs in the beſieging of Cities; nor has the horrid Noiſe of the breaking of the Shell diſturbed them. I knew a certain Gentleman, otherwiſe not much addicted to Sleep, who taking a long Journey on Foot, and being much fatigued with the Summer Heats, ſlept ſo profoundly that he did not hear the breaking open of his Chamber-door, nor the tumultuous Noiſe of People in his Chamber. Soldiers being wearied out by Day and Night in the beſieging of Cities, learn to ſleep by the Sides of the Mortars, from whence are thrown Iron Shells full of combuſtible Matter.

[9] This has been well expreſſed after *Homer* by *Ovid* in elegant Verſe (*Metamorph.* II.). Certain it is that when a Man in Health is placed where none of the Senſes can be affected, where no Light can be ſeen, or any Noiſe heard, no Uneaſineſs to irritate the Body, nor any Care, Reaſonings, or Reflections to diſturb the Mind; that Man will ſoon fall into a Sleep whether before or after Dinner; or even though he ſlept the whole Night before, provided no Object or Motion of the Body excites his Spirits. I have ſeen Philoſophers in the deepeſt Meditations fall into a Sleep, unleſs the falling of the Book in which they were reading excited the Spirits to Motion.

[10] Almoſt every body is inclined to ſleep in the Noon Heats of the ſultry Dog-days.

[11] There is not any kind of Sleep more fatal, than that which proceeds from intenſe Cold; and in this manner I had like to have ſlept in the Year 1709, going in company with a Surgeon in a Coach to ſee a Lady who had broke her Leg at a

Place two Miles diſtant from *Leyden*, the Winter being extremely ſevere. For both myſelf, the Surgeon and Coachman were ſeized with ſuch a Sleepineſs, accompanied with ſuch an inexpreſſible Pleaſure, that they would certainly have fallen Victims to the fatal Pleaſure, if I had not been aware of the Danger, and adviſed my Companions to get out of the Coach and ſtir their Blood by walking; by which means the Sleepineſs was ſhook off, and every one came to himſelf. They who walk through the Snows in the moſt ſevere Cold, are taken with an almoſt inſuperable Propenſity to ſleep; but if they give way to the fallacious Inclination, they will ſleep a perpetual Night without ever waking again.

12 Old People, whoſe Heat is almoſt entirely exhauſted, are continually ſleeping; and at length ſleep into Death. On the contrary, a moſt intenſe Fear produces a Carus, and Sleep which is no leſs fatal.

13 The excellent Anatomiſt *Drelincourt* having tied down a moſt fierce Dog upon his Back, uncovered the Carotid on each ſide, and fixed a Ligature upon each, whence the Animal continually ſtaggered, and fell into a moſt profound Sleep; but when the Ligatures were taken off, the Animal returned to his former State of Vigilance: it therefore follows, that the intercepting the Courſe of Blood to the Brain cauſes Sleep; and it is remarkable that the Experiment ſucceeds, though the vertebral Arteries are not at all compreſſed by Ligature.

14 Every Cauſe which compreſſes the cortical Part of the Brain, the Impetus extending to the Medulla, infallibly produces an Apoplexy. In the moſt ardent Fevers the Patients are watchful at the Beginning of the Diſeaſe, and as the

Diſeaſe

Diſeaſe advances they become delirious, which Delirium being increaſed they become raving with perpetual Vigils, and at length periſh with a Carus or Apoplexy; namely, a continual Sleep joined with a moſt acute Fever.

15 When all the Nerves are at reſt, Sleep eaſily follows.

16 Too profuſe Evacuations prove fatal likewiſe by inducing Sleep. And hence it is that in Wounds accompanied with a profuſe Hæmorrhage, a deficient Pulſe and Sleepineſs are very bad Signs. The like is alſo true when a great Portion of the Blood is in a manner intercepted from the Body by ſome internal Cauſe. In Animals killed by cutting the jugular Veins, a Snoring and Sleepineſs follow, which is intercepted by Convulſions.

17 Such a phlegmatic Diſpoſition of the Blood as accompanies a Leucophlegmatia, and which is ſucceeded by a Lethargy. I ſaw a Profeſſor in this Univerſity whoſe Blood was ſo thick and ſluggiſh that he was almoſt perpetually ſleeping, and choſe to be rather thus continually abſent from Life, than to be truly dead.

18 The more corpulent or fat a Perſon is, the more the Arteries and Veins which lie under the Skin are compreſſed; and therefore in fat People the Arteries and Veins are much ſmaller than in thoſe who are lean. But among all the Parts of the Body, the Brain only contains no Fat, and remains free from being compreſſed by that Subſtance. Therefore the carotid Arteries will remain free while the other Veſſels are compreſſed; and thus the Blood will be derived with a greater Force to the Cortex of the Brain, and will by its Preſſure produce continual Sleepineſs. I have ſeen very fat People, for whom I have had a great Eſteem, fall into a Paraplegia, when by walking in the Summer

Heats

Heats the Fat has been fuſed and forced into the Veſſels of the firſt Order; from which Palſy they have been cured by bleeding and purging with Acids, as Cryſtals and Cream of Tartar, *&c.* About two Years ago (*anno* 1724.), I ſaw a Phyſician who was very fat, and who oppoſed or rather increaſed an imaginary Plethora by repeated bleeding, till at length he arrived at ſuch a degree of Sleepineſs, that he has ten times fallen aſleep in the midſt of his Diſcourſe with me. I perſuaded him to uſe Salt and the Eſſence of Wormwood, by which means I cured him. Such People as theſe are the better for Cares, Watchings, Labours, Exerciſes, ſpare Diet, acid Drinks, Vinegar, Spices, *&c.*

[19] Such Wounds as extravaſate the Blood, whence follows a Compreſſure of the Dura Mater and Brain.

[20] In the Sepulchretum Anatomicum of *Bonnetus*, we are furniſhed with Hiſtories of People diſſected after dying of moſt acute Diſeaſes with Sleepineſs. In theſe the ſmall Veſſels in the cortical Part of the Brain generally appeared ſtuffed full with red Blood, which in a healthy State they never admit.

[21] In Infants the eight Bones of the Skull are ſo looſely joined together by Suture, that one may eaſily compreſs their Brain and render them apoplectic. Women ſometimes ſecure the Heads of Children with ſuch ſtrait Caps, as throws them into Convulſions; and if the Force was a little more violent, they would be deſtroyed with an Apoplexy. But theſe Diſorders are eaſily removed by removing the too great Stricture from their Head. I mentioned the Caſe of a Woman who had loſt Part of her Skull before at §. 284.

Drelincourt

[22] *Drelincourt* has made the Experiment upon Dogs, who after their Brain had been cut out, lived without Senſe and Motion like Vegetables.

[23] When the Cerebellum is affected in the ſame manner, as the Brain is affected to produce Sleep, inevitable Death is at hand. They who have ſuddenly a moſt ſevere Pain of the Head followed with a loſs of Speech, periſh of an Apoplexy within the ſpace of three or ſeven Days, ſays *Hippocrates*. Upon opening the Bodies of ſuch People, among other Cauſes Blood has been moſt often found extravaſated from ſome ruptured Veſſel into the Ventricles of the Brain, ſo as to compreſs its Medulla. But, as we obſerved before, the arched Part of the Ventricles is the common Senſory itſelf (§. 568.), that is to ſay, the Beginning of the whole Medulla of the Brain; no wonder therefore if Sleepineſs follows from a Preſſure upon this primary Origin of all the Nerves. But when the extravaſated Blood penetrates to the fourth Ventricle where the Cerebellum lies upon the Medulla oblongata, and inſerts its own Medulla in four Places into the Medulla of the Brain; in that caſe the Medulla of the Cerebellum is alſo compreſſed, the Extremity of which Medulla unites itſelf with the Medulla of the fourth Ventricle which is in form of a Pen, whence Death itſelf follows. In a word, a Compreſſure of the Brain excites Sleep, and even the moſt profound Sleep, an Apoplexy; which is not curable but by removing the Blood which compreſſed the Brain; but the Cerebellum being compreſſed occaſions a perpetual Sleep, namely, Death itſelf.

§. 592. Sleep is impeded or hindered,

1. By a continual and ſlow Mixture of *warm* [1] watery Liquors with the Blood.

2. By

2. By every thing which is ſharp or capable of *vellicating* [2] the Nerves of the Brain.

3. By ſtrong *Paſſions* [3] or Affections of the Mind.

4. From an Irritation of the Brain itſelf, whether from an external or an *internal* [4] Cauſe.

[1] When we are concerned in urgent Buſineſs, which will not admit of being interrupted by our Sleep, nothing will more certainly keep off Sleep than Abſtinence from ſolid Food, with the drinking of fleſh Broths to the quantity of an ounce or two every half Hour; or inſtead of Broth, Tea, Whey, or any other thin Liquor often repeated. By this means Sleep may be drove off for a long time; and I remember that by theſe means Doctor *Sherrard* continued three Days and Nights without Sleep. I do not recommend this Secret to drive off the neceſſary Sleep but upon extraordinary Occaſions, for I am too well acquainted that by this means the vital Powers are infringed, and Life itſelf ſhortened or rendered more calamitous; in a word, I have ſeen the fatal Effects of being deſtitute of the natural Sleep in many of my Friends.

[2] So long as the Spirits in the Brain are agitated, Sleep cannot take place. So long as any acrid Matter is applied to the Nerves, it continues to affect the Brain, and will induce Vigilance till either the Nerve is deſtroyed, or the irritating Matter removed. In *Denmark* there is a cruel kind of Torment, being a kind of military Puniſhment, in which the Offender is obliged to ſtand with his naked Feet upon an Iron Bar full of Spikes; ſo that when he falls aſleep, he runs againſt the

the Iron Spikes and is awaked, till a new Occaſion of ſleeping comes on, and he wounds himſelf again; and by this Puniſhment he is obliged to confeſs the Truth. The *Venetians* have a ſevere kind of Torture, in which the Offender is included in a Barrel beſet with Spikes on the inſide; ſo that on which ever ſide he lies he will be wounded.

[3] For theſe Paſſions or Affections are intenſe Changes in the common Senſory, ſometimes ſo laſting, that the Perſon can never reſt, new Motions continually ariſing in the Mind; and hence Watchings ariſe from Anger, Fear, Deſire of Revenge, Grief, *&c.* Thus *Homer* poliſhed his Bed by thinking upon *Ulyſſes*, as Women are uſed to poliſh Metals.

[4] As, for Inſtance, from a ſlight Inflammation of the Brain. I have ſeen Men who in the Beginning of acute Fevers, have continued without Sleep for the ſpace of ſeven Days and Nights, eſpecially in the Beginning of a Phrenzy.

§. 593. Sleep therefore is that *State* [1] of the Medulla of the Brain, in which the Nerves do not receive ſo copious and ſtrong an Influx of Spirits, as is required for the Organs of Senſe and voluntary Motions, to exerciſe their Functions with Eaſe, and with Expedition.

[1] It is in ſhort a Reſt of the animal Faculties, by which I underſtand all the Senſes and voluntary Motions. Watching is when all the animal Faculties, namely, the ſeveral Motions and Senſes of the Body are capable of being readily performed; or it is that Diſpoſition of the Spirits of the Nerves by which they are adapted to be received, tranſmitted, and to fill the Syſtem of the Nerves reſulting

ſulting from the Brain only, as we are aſſured by Experiment. For if but three Ounces of Blood are extravaſated from a ruptured Artery of the Brain, ſo as to compreſs the Dura Mater, in that caſe the Action of the Heart will remain the ſame or become ſtronger, and the Reſpiration will be perfect; but neither will the Perſon ſee nor hear, perceive or imagine any thing, nor will he remember, judge or reaſon, nor yet move any of the voluntary Muſcles, nor be affected with any Paſſion of the Mind. But in this caſe the Brain only is affected, and from its being affected in ſuch a manner does Sleep ariſe. Natural Sleep therefore follows when there is ſuch a phyſical Change or Condition in that Part of the Brain, which is the Seat of the common Senſory, that the Spirits or Juices of the Nerves ſtagnate or become perfectly at reſt, whether that being from an impeded Secretion of them, or from ſome Change in the Circulation. In Sleep therefore all the Actions ceaſe, which maintain the Commerce betwixt the Body and Mind; while thoſe Actions only are continued which belong to the natural and vital Humours. Sleep is therefore an Affection of the Brain excluſive of the Cerebellum; and in the Brain Sleep may be termed that State in which the Motion of the Humours is impeded through the moſt ſubtle Veſſels the Nerves, ſent from the Brain to the Organs of Senſe and voluntary Motion. Having proceeded thus far, it now remains for us to determine that State of the Brain from whence Sleep ariſes alternately during Life.

§. 594. The proximate Cauſe therefore of Sleep is perhaps a Paucity or *Deficiency* [1] in the moſt ſubtle Spirits, which being now ſpent or exhauſted

exhauſted require a long time and great Apparatus to prepare and recruit the ſame; hence therefore the fineſt Veſſels being emptied, or not ſufficiently repleniſhed, will collapſe for a time; or the Preſſure of the *groſſer* [z] Part of the Blood upon the Cortex of the Brain, which every way inveſts the Medulla, may be ſo great as likewiſe to compreſs the latter, and intercept the Courſe of the Spirits into the ſame Medulla.

[z] When the Spirits are conſumed in a certain proportion, Sleep follows. This Juice which we ſometimes call Spirits is depoſited from the Cortex of the Brain into the Medulla, and employed as well in the Nerves of Senſation as in thoſe which go to the Organs of voluntary Motion, in which this Juice ſeems to be exhauſted or ſpent in a given time; but then there being no Fluid capable of entering theſe moſt minute Tubes to ſupply the place of that which has been conſumed, in conſequence of that follows Sleepineſs. For there is a certain time deſtined for every Humour in the Body to be ſeparated, prepared, and perfected from the Chyle, Blood, Serum or Lymph; as there is alſo a certain time wherein thoſe Juices are conſumed, agreeable to the Laws of the animal Œconomy. From a certain quantity of Aliments in a given time is prepared a certain quantity of Urine, inteſtinal Fæces, perſpirable Matter, *&c.* The Formation of the Chyle is limited to a certain time, as alſo is the Preparation of Milk from thence, with the Formation of Blood from the ſame. In oviparous Animals, the Albumen of the Egg is ſo attenuated within the ſpace of about twenty Days, not much ſooner nor later, by the Heat of the ſitting

ting Hen, that from the Albumen are produced all the Members of the Chick, but that Liquor which ſeems to be contained in the ſmalleſt Veſſels of the Brain muſt conſequently be the moſt elaborated of all the Humours in the Body. For in the larger Veſſels the groſſer Humours only are contained, namely, in the ſanguiferous Veſſels which receive the Humours, which are as yet the moſt remote from an animal Nature; namely, the Chyle is received into them. But the more any Veſſels exceed the largeſt in Smallneſs, the more ſubtle are the Liquors which they convey; ſo that in the ſmalleſt Veſſels of all, that Liquor is admitted, from whence reſults all the Actions of the human Body, and whoſe Particles are ſmall enough not to exceed the Capacity of the leaſt Veſſels of the Nerves. From hence we infer, that to the Formation of animal Spirits, all the Actions of the human Body are required to concur, and that thoſe Spirits are generated as they are conſumed within a certain ſpace of time; and from hence again it follows, that there muſt be a time in which few or no Spirits paſs into the ſmalleſt Veſſels from the Blood applied to the cortical Fabric of the Brain, and that therefore theſe ſmalleſt Veſſels will collapſe, in conſequence of which follows a Propenſity to ſleep. Hence it follows, that the more violently the Body is exerciſed by the voluntary Motions, the ſooner will there be a Neceſſity and Inclination to ſleep; and from hence Sleep is ſaid by a Proverb of *Solomon* to be the moſt pleaſing to the Weary and Poor. Wearineſs and Sleep follow Exerciſes of the Body, becauſe the moſt ſubtle Juices are diſſipated by the Motions of the Muſcles. Therefore a Perſon who in Health prepares only ſo much Spirits in the ſpace of twenty-four Hours, as are ſufficient to keep him waking

ſixteen

ſixteen Hours, he will require ſix or eight Hours for a Ceſſation of that Diſpendium of Spirits, that the Body may prepare the Matter of the nervous Juice and form the ſame into Spirits; ſo that theſe ſix or eight Hours are requiſite for Sleep. But the direct time neceſſary for Sleep cannot be abſolutely determined, ſince more Sleep is naturally required in proportion to the loſs of Spirits during the time of Vigilance.

When the venal Blood is mixed with many crude, groſs and coheſive Particles which have not yet been ſufficiently attenuated; or when a great quantity of Chyle is ſent into the Veins, Sleepineſs follows from a Turgeſcence of the Veſſels in the Brain, which Sleepineſs may be continually removed by opening a Vein. *Sanctorius* has obſerved that from eight Pounds of Aliments taken into the Body within the ſpace of twenty-four Hours, five Pounds of them exhale by inſenſible Perſpiration. But the Particles which are thus exhaled muſt neceſſarily be ſupplied by others; and therefore when a Perſon ſleeps but once in twenty-four Hours, he will become ſleepy all that time during which the crude Chyle mixes with the Blood after Dinner. Hence it is natural for Animals to ſleep when they are filled with Aliment. No Arteries in the Body are more dilatable from the Thinneſs of their Coats than thoſe of the Brain, which yet are reſiſted and ſtrengthened by their including Cranium (§. 234.). When therefore the Blood fills the Arteries of the Pia Mater to a great degree, they will take up a larger ſpace, and conſequently compreſs the other Parts of the Encephalon into a leſs compaſs; and hence Sleepineſs follows from the drinking of ſpirituous Liquors: for ſuch Liquors act upon the ſmall Veſſels of the Brain, as Vapours aſcending into the Head of a Still, name-

ly, finding no Vent they cauſe a Rupture. Thus therefore ſpirituous Liquors rarify the Blood in the Brain and diſtend the ſmall Arteries, which again compreſs the other ſmall Veſſels, whence Sleepineſs follows, and continues until the Equilibrium is reſtored betwixt the ſanguiferous Veſſels of the Brain and thoſe of the other Parts of the Body.——Hence then we infer, that the natural Cauſes of Sleep are, 1. A Conſumption of the moſt ſubtle Humour of the Nerves, not ſufficiently ſupplied during the time of Vigilance. 2. The Mixture of new and crude Chyle with the Blood, which renders the latter more thick and impervious through the ſmall Veſſels of the Encephalon. The *Romans* uſed neither Breakfaſt nor Dinner, but Suppers only, after which they uſed to compoſe themſelves to ſleep, which they extended generally to a long interval of time: and we obſerve, that Animals ſearch out for a quiet reſting Place as the Night approaches, having firſt ſupplied themſelves with new Food.——Beſides theſe Cauſes of Sleep there are innumerable other preternatural Cauſes, ſuch as a Plethora, a Rarefaction of the Blood increaſing the Preſſure upon the Cortex of the Brain, a Leucophlegmatia, *&c.* which do not fall under our Conſideration in this Place; ſince we here endeavour to explain only the Cauſes from whence the alternate Viciſſitudes of Vigilance and Sleep follow. Add to this, that the Spirits generated in the Brain may be conceived to be more ſubtle than thoſe of the Cerebellum; whence a greater Diſpendium of the former may be required to maintain theſe phyſical Actions, and for the ſame Reaſon too the former may be ſooner exhauſted.

§. 595. The Cauſe therefore of natural Sleep, may be every thing that can produce theſe two Particulars, (§. 594.) §. 596.

§. 596. From hence we may be able to underſtand the Effects of Sleep, during the time of which ſeveral *Actions* [1] of the Body ceaſe; (§. 593. N°. 1, 2, 3, 4.) which Organs together with the *Muſcles* [2] (§. 590. N°. 3.) are in a State of Reſt; the Spirits difficultly *flow* [3] through them (§. 593.), and are therefore leſs *conſumed* [4], while at the ſame time the ſolid Fibres both in the Nerves and Muſcles receive little *Alteration* [5] and are not wore away, but an *Equilibrium* [6] is procured in all the Veſſels throughout the Body; the Humours being ſent through the Veſſels with an equable Preſſure and with an equable *Velocity* [7].

[1] That is to ſay, all the animal Actions, the five external and internal Senſes, with the Motion of the Muſcles ſubject to the Influence of the Will; which Actions perfectly ceaſe in Sleep, though if we compare them, we ſhall find that they require much greater Supplies than all the vital Actions taken together. No one will deny, that a Horſe which has ſtood twenty-four Hours at Reſt in a Stable muſt ſuffer a leſs Motion and Conſumption of his Organs, than if he had been running all that time with ſomebody upon his Back. The Actions therefore of People who are awake, are much more weighty and numerous than the vital Actions of thoſe who are ſleeping; and therefore moſt of the Actions of the human Body ceaſe during the time of Sleep. Even a Perſon cannot ſo much as ſpeak but the Blood will be agitated more ſwiftly, and therefore they who pronounce aloud with a quick and clear Voice, are by that means

as much fatigued as if they had been running. We may even become too hot by too intenſe and profound Meditation. But all theſe Actions which make up the greater Part of thoſe which employ human Life, ceaſe during the time of Sleep.

[2] All the Muſcles which are tenſe and in Action while we are awake, are flaccid and at Reſt during the time of Sleep. Even the moſt common Obſervations teach us, although they are neglected from their Familiarity and Eaſineſs, that the Muſcles of the human Body are always in Action when we are not aſleep. You would perhaps believe that a Man does not labour when he ſtands erect, becauſe that Action is ſo familiar that it communicates no Idea of Force to the Mind; but at the ſame time if a Perſon ſtands with his Arms extended, the Action will be found very violent and painful: for then the Muſcles of the Toes, Meta-tarſus, Tarſus, Legs and Thighs, with thoſe of the Pelvis and Vertebræ of the Spine, from the Os ſacrum even to the Atlas, with thoſe of the Head and Thorax, all operate as it were in a determinate manner (§. 639.). That they do thus act while we are awake, notwithſtanding our Inſenſibility thereof, is evident from obſerving the Poſture of the Body when it is inclined to ſleep; for the Muſcles then ceaſing to act, the Body inclines one way or the other, and the Parts collapſe uſually into the moſt looſe and eaſy Poſture. The Organs of the Body therefore which acted while we were awake, ceaſe from their Operation during the time of Sleep. But theſe Organs are the voluntary Muſcles which become flaccid in Sleep, and do not tranſmit their Humours as is uſual in the time of Vigilance.

[3] For if in the time of Sleep the animal Spirits flowed through the optic Nerve to the Retina, or through

through the auditory Nerve to the Veſtibulum, there could not be the leaſt Reſt either in the common Senſory or in the voluntary Muſcles; but in Sleep we affirmed that the Organs of Senſe and voluntary Motion are at Reſt, and therefore the Cauſe which uſed to move thoſe Muſcles does not move through them while we are aſleep. In a Perſon who is awake the Arm may be eaſily extended; but ſo ſoon as that Man is in a ſoft Sleep, the Arm will be continually pulled down by its Weight; and therefore at that time that Cauſe ceaſes to enter the Muſcles which rendered them tenſe and ready for Contraction; but that Cauſe is the Will or Mover of the Spirits through theſe Organs of Motion, and therefore the Spirits themſelves are at Reſt.

[4] Nothing will exhale nor any Part be preſſed to Action, ſince there is no new Supply of Spirits received.

[5] It is an univerſal Law, preſcribed to all Bodies, that the ſeveral continuous Particles or Elements of the ſame Body attract each other; and therefore the Cauſe which diſtends the ſame Body muſt diſtract the elementary Particles from their Connection. But when the Cauſe of Attraction only remains while the diſtracting Cauſe is removed, then the Power of the former is continually increaſed, ſo as to bring thoſe adjacent Particles as near as poſſible to each other in the ſame Body. Therefore the Fibre of a Muſcle which is free from all Diſtenſion, will reſtore itſelf to its former Shortneſs; and hence a Muſcle which has not been moved for a long time becomes at laſt immoveable. Surgeons obſerve in a Fracture of the Ulna, that if the Part affected is ſecured with Dreſſings and Splints, and not moved for the ſpace of ſix Weeks ſucceſſively,

after removing all the Bandages, the Flexion of the Cubitus or Elbow will be then found impracticable; and therefore the Muſcles concrete together, merely by long continued Reſt. But the ſmalleſt Veſſels not being diſtended, have their Sides grow together in the ſame manner, ſo as almoſt to form ſolid Threads. The ſame Accident may alſo ariſe from the Nerve being compreſſed by the Artery.

[6] While we are ſleeping there is an Equilibrium produced betwixt the Heart and Blood-veſſels; for when the animal Spirits are wanting in the cortical Subſtance of the Brain, the ſanguiferous Veſſels being then leſs preſſed will be more diſtended; and on the other hand the medullary or nervous Tubuli will be then more compreſſed. Therefore the Influence of the Mind upon the Heart ceaſes, while all the Veſſels are in Equilibrium with reſpect to the Heart, which is almoſt placed in the Center of Gravity; and therefore as the Circulation of the Blood depends entirely upon the Heart, it conſequently follows, that the Motion thereof muſt be extremely equable during Sleep. But in the mean time in what Office is the Mind employed? Whether or no is it idle? No one will pretend to ſay, ſince the Memory does not act during perfect Sleep. When we are inclining to ſleep there remains as yet ſome Conſciouſneſs and Memory; but in a profound Sleep, there does not ſeem to be the leaſt remains either of Memory or Conſciouſneſs.

[7] For at that time the Blood is equally diſtributed to all Parts of the Body, and every Part takes its due quantity, agreeable to its Magnitude and Diſtance from the Heart.

§. 597. But

§. 597. But in Sleep the Motion of the *Heart* [1] and Lungs, with the Actions of the *Arteries* [2] and *Viſcera* [3] are increaſed (§. 590. N°. 5, 6, 7.); nor is there any Change or Deſtruction at that time made in them from the Action of the Senſes and *voluntary Motion* [4] then ceaſing (§. 590. N°. 1, 2, 3, 4.); and therefore theſe Effects follow from thoſe Actions which immediately depend thereon, and may be reckoned, 1. A ſtronger and more equable Circulation of the *vital* [5] Humours through the Veſſels, which are then more free, lax and open, without being impeded by the various Contractions of the Muſcles; hence therefore the Impulſe of the Humours into the *lateral Veſſels* [6] is indeed leſs but more equable, and the Impulſe of them through the larger Veſſels is likewiſe ſtronger and more equable; thus therefore the ſmall lateral Veſſels will be gradually filled, will tranſmit leſs of their Humours, and at length in a manner quite *reſt* [7] or ſtand ſtill with their contained Fluids; the lateral *Follicles* [8] or Cells of the adipoſe Membrane will be filled and diſtended with the more ſlowly moving Oil or *Fat* *[8], as will be alſo the Follicles of the ſeveral Glands with their reſpective Juices; ſo that at length the Circulation continues almoſt only through the ſanguiferous Veſſels, becoming gradually ſlower and at laſt ſcarce perceptible, if Sleep is too long continued; and in the mean time the accumulated Fat defends the internal Parts like

a Balſam ſpread round them, and affords ſlowly ſome ſmall *Nouriſhment* 9 when there is urgent Neceſſity. 2. In moderate Sleep then the Matter of the *Chyle* 10 is very commodiouſly changed into Serum, the Serum into ſtill thinner Humours, and thoſe thinner Humours into the Matter of Nutrition. 3. The Attrition of the ſolid Parts which ſlightly cohere together, becomes gradually more gentle. 4. The Secretion of the *Skin* 11 is increaſed, while the other Secretions are diminiſhed. 5. The *loſt Subſtance* 12 is at this time beſt repaired, ſince the Humours are renewed by a continual juſt and *equable* 13 Repletion, and the *ſolid Parts* 14 at the ſame time are beſt repaired, ſince the Cauſes which impede, diſturb, or deſtroy Nutrition then ceaſe; and in the mean time that the nutritious Matter is moſt happily prepared, there is an Aptitude in the Veſſels to receive the ſame, and a Diſpoſition of the Humours to enter into them, while the Cauſes which apply and conſolidate the nutritious Matter at the ſame time freely act. 6. Hence therefore there is a new Production and Accumulation of animal *Spirits* 15 or at leaſt the Matter of them throughout all the Humours, and an Accumulation of them in the ſmalleſt Veſſels which are thus filled.

[1] That the Motion of the Heart is increaſed appears from the Pulſe (§. 590.) and increaſed Heat; but the Heat of the Body is not increaſed, but by a ſwifter Contraction of the Heart diſcharging more Blood in a given time; but more Blood

Blood cannot be expelled from the Heart, without more being received and conveyed from the right Ventricle to the left; nor can this laſt be performed without a ſwifter Protruſion of the Blood through the Lungs, which muſt be neceſſarily accompanied with a more quick Reſpiration.

[a] The Force of the Arteries is that Reſiſtance by which they oppoſe Dilatation from the Heart, (§. 213.) and the Meaſure of their Force is the ſame with that of the Impulſe of the Blood received from the Heart (§. 215.). Since therefore the Contraction of the Arteries is equal to the Contraction of the Heart, it follows, that increaſing the Force of the Heart will increaſe the Action of the Arteries. But if this Argument is denied, and you ſuppoſe the Force of the Heart to be increaſed while that of the Arteries remains the ſame, thoſe Veſſels will then be continually more and more diſtended with Blood beyond what their Force is capable of propelling; whence after a few Pulſations Death itſelf muſt follow. If then the Force of the Heart is increaſed in the time of Sleep, that of the Arteries muſt be likewiſe increaſed proportionably; whence it follows, that the Action of all the Viſcera upon the Blood and their ſeveral Humours will be increaſed, for all the Viſcera are compoſed of mere Arteries. All the Cauſes therefore which reſult from the Action of the Heart and Arteries, will be ſtronger in Sleep than during the time of Vigilance.

[b] That is to ſay, ſo far as the Viſcera are moved by the vital Powers; for they are ſubject to a very inconſiderable Motion, from the Influence of the Mind by the Nerves. The animal Motion indeed exceeds the Motion of the Humours in Sleep; namely, when *Farenheit*'s Thermometer deſcends to the thirty-ſecond Degree, Water freezes; but

if

if it falls to the tenth Degree, all Animals then expire if they ſleep (without any Covering) expoſed to the external Cold. For the vital Motion only cannot then prevent the freezing of the Humours. But ſuch a Degree of Cold fatal to thoſe who ſleep may be overcome by running in the open Air, or by other violent Exerciſes and voluntary Motions of the Body; whence it follows, that the animal or voluntary Motion of the Body generates a greater Heat than the vital Motion only.

'Which Motions in a Perſon who is waking, produce a great Variety of Alteration in the Action of the Arteries and Veins; but which have now no Influence when the Action of the Heart only continues. In Sleep the Action of the Heart continues equally the ſame, to which the Action of the Arteries correſpond, together with the Action of the Viſcera, which are all compoſed of Arteries. The Application therefore of the Powers of the human Body to aſſimilate the crude Juices is on all Sides increaſed, and at the ſame time rendered equable. The aſſimilating Powers therefore act moſt when the other Powers are at Reſt.

'Namely, thoſe Humours which paſs through the Heart to the Lungs, from thence to the Arteries and Veins, and then again to the Heart in a continual round; but not thoſe Humours which flow into the lateral Veſſels, for the Motion of theſe is almoſt ſuppreſſed while their Impetus is increaſed.

'By the lateral Veſſels we intend the ſerous Arteries, with the lymphatic, perſpiring and nervous Veſſels, *&c.* In a Perſon who is ſleeping the Pulſe and Heat increaſe; but Heat reſults from the Action of the Veſſels of the firſt Order, that is to ſay, of the Blood-veſſels both Arteries and Veins, from whence all the other Veſſels derive their

their Heat; and therefore ſince Heat is increaſed in Sleep, it is evident that there is a greater Action of the ſanguiferous Veſſels at that time. But then the Juices which are conveyed through the ſmaller Veſſels muſt neceſſarily ſtagnate in the time of Sleep. For theſe ſmaller Veſſels are filled by the Action of the ſanguiferous Arteries and their Contents, and are not ſo much moved forward by the Action of the Veſſels themſelves, as by the various Motions of the adjacent Muſcles protruding them towards the Heart: For while we are ſleeping the thinner Humours continue to paſs off from the ſanguiferous into the ſerous Arteries; ſo that the ſanguiferous Arteries being gradually exhauſted in Animals that ſleep whole Months together, towards the End of their Sleep the Pulſe is ſcarce perceptible. Thus the Serum is derived from the ſanguiferous Veſſels into the ſmaller ſerous Veſſels, where it ſtagnates without circulating. There are ſome who believe that the Serum cannot thus ſtagnate becauſe it is propelled forward by the ſucceeding arterial Blood, in the ſame manner as the Liquor contained in one Leg of a Siphon, does by its deſcending Weight raiſe that which is contained in the other Leg. For all the Veſſels of the Body, ſay they, may be compared to an inflected Tube or Siphon, ſo that the Humours contained in one Leg cannot deſcend without raiſing the other; and the Liquor contained in one Leg may cauſe that in the other to deſcend. But it may be eaſily proved by Experiment that this is without Foundation. Let a Perſon ſit ſtill a whole Day, and he cannot be ſaid to be truly at Reſt, for he will move ſometimes one Muſcle and ſometimes another; ſo that in that State of ſuppoſed Reſt the Humours will continue to be propelled through the lateral Veſſels. But let the Perſon

ſleep

ſleep in the ſame Chair but a whole Night, he will be ſurpriſed in the Morning to find his Legs ſwelled as in a Dropſy, even though he was before in Health; but by walking this Tumor of the Legs is ſuddenly diſperſed. Our Humours therefore ſtagnate in the ſmaller Veſſels, not ſo much from their Weight, as from the Deficiency in the Action of the Muſcles; for want of which the Humours propelled into the lateral Veſſels remain there ſtagnant without being propelled farther, ſince they are placed farther from the Power of the Heart.

[7] The Diſtribution continues equable, but the groſs red Blood cannot paſs into the ſerous Veſſels, and all the other Juices ſtagnate in their reſpective Veſſels. Hence when Sleep has been continued a long time, the Circulation is little or nothing, except through the ſanguiferous and ſerous Arteries, and ſuch as cannot be compreſſed as having no adjacent Muſcles, namely, the Medulla of the Brain and Spina dorſi. Hence Animals which I have kept in large Veſſels for ſeveral Months, I have found living and not at all conſumed.

[8] No Animal can be fat ſo long as the animal Motions are ſtronger than the vital; but Sleep renders People fat, ſince none of the Humours are more viſcid than the Oil or Fat. In ſleeping Animals therefore this tenacious Fat will be depoſited into the adjacent Cells of the adipoſe Membrane, till at length the Animal is buried in his own Fat.

[*6] It is well obſerved of the Poet *Martial*, (*lib.* 13. *epig.* 59.) that the wild Mouſe commonly called a Dormouſe ſleeps all the Winter, and is even fatter at the time when it receives no other Suſtenance but from Sleep. Theſe kinds of Animals towards the latter End of the Winter have ſcarce any Motion. I obſerved ſomething wonderful in the Tortoiſe, which Animal has in a manner

manner four Hearts and Lungs, and is able according to different Circumſtances to propel the Blood either through the Heart only without pervading the Lungs, or through the Heart and Lungs together, breathing at the ſame time according either as it uſes or abſtains from muſcular Motion. This has been well conſidered by the excellent Anatomiſt *Du Verney*, in the Memoirs of the Royal Academy, *ann.* 1693. *p.* 310. Towards the Beginning of Winter the Tortoiſe buries itſelf in the Sand, ſo that it is hard to diſcover where it lies hid, and thus it lives without Reſpiration, creeping farther under the Earth in proportion as the Cold is more ſevere. But at the Return of Spring it by degrees creeps nearer to the Surface, and at length comes out of the Sand, leaving no Marks by which one can trace out the Place where it lay; and being thus expoſed to the Air, it is both vigilant and breathes. But even the more active Animal the Swallow lies dormant without Motion five Months in the Year; and the ſame is alſo true of Frogs. Likewiſe the Bear, the Badger and Dormouſe paſs the whole Winter in Sleep without Food. But ſince in theſe Animals the adipoſe and glandular Cells are not emptied of their Contents, by the Motion of the Muſcles ceaſing for ſo long a time; therefore Fat is accumulated in them, and thoſe Diſorders frequently produced which ariſe from a Diſtenſion of the Glands.

9 Animals which ſleep a long time do at laſt prey upon their own Fat, which returns into the Blood (§. 333.). The Bear paſſes the moſt ſevere Winter by ſleeping in his Den, where he at firſt ſleeps and ſnores very ſoundly, and then growing by degrees hotter, he ſweats out a kind of Oil, with which the whole Animal is bedewed as with Lard; but at laſt the Blood becoming more acrid

conſumes

conſumes this Lard, till at length the warm Seaſon returning awakes the Animal. If you kill this Beaſt in the midſt of the Winter in his Den, he is found very fat, but in the Spring he comes forth from his Den extremely lean and almoſt like a Skeleton. Hence therefore it is evident that during the firſt Part of this Animal's long Sleep an Oil or Fat is ſeparated from the Blood, with which the Body is preſerved and ſupported; but at length this Oil being diſſolved and returned into the Veins, ſupplies the Blood inſtead of Chyle.

[16] In Sleep the Motion of the Blood is increaſed through the Arteries and Veins of the firſt Order; by which means eſpecially the crude Chyle is attenuated. Hence therefore during Sleep the Chyle is converted into Milk, Milk into Serum, and Serum into Blood; but the Blood itſelf is at the ſame time attenuated again into a ſecond Serum, and that into a more thin Lymph in ſeveral degrees of Tenuity, being at laſt elaborated into the animal Spirits themſelves. This Elaboration is alſo promoted by the Atmoſphere of warm Vapours proper to every Perſon, which is retained by the Bed-cloaths, and being returned upon the whole Body, warms and relaxes like a vaporous Bath.

[17] A healthy Perſon ſleeping eight or at moſt ten Hours, becomes conſiderably lighter than if he ſlept not ſo long (§. 430.). When a healthy Perſon ſleeps eight Hours he will not perſpire much during the firſt five Hours, but the three laſt Hours he will perſpire copiouſly, and will become much lighter, as is evident to the Senſe and by the Steelyard, as *Sanctorius* has obſerved. For the crude Humours are during the firſt five Hours attenuated and digeſted by the repeated Action of the vital Powers, ſo as to be afterwards eaſily exhaled during the laſt three Hours.

During

[12] During Sleep the nutritious Elements or Particles are equably diſtributed to the ſeveral Parts required to be nouriſhed.

[13] Men and other Animals ſleep with their Limbs inflected or drawn up, by which means the Veſſels are compreſſed and a greater Reſiſtance is made to the Circulation by increaſing the Number of Inflexions and Angles; whence the Attrition and Heat of the Blood is increaſed.—But when Animals are hot they ſtretch themſelves out.

[14] During the time of Vigilance the Action of the Muſcles extend the Nerves and Fibres of the Body, compreſs the Blood-veſſels, *&c.* (§. 402.); whence Attrition and Laſſitude follow: but during Sleep the Vacuities which were formed in the time of Vigilance by an Abraſion or Diſlocation of the nutritious Particles, are again filled up with Particles like the former (§. 445.). The time of Vigilance therefore deſtroys the Body, but during Sleep it is repaired. After the Body has been exerciſed to great Wearineſs, a Pain is felt throughout the whole; but if then laudable Sleep follows, the Perſon ſoon after perceives himſelf in a manner renewed; namely, in the Day-time the muſcular Fibres labour till they are almoſt broke aſunder, from whence follows that Pain and Wearineſs; but in the Night-time by Sleep, the Parts are equably repleniſhed and repaired, ſo that the former Strength is in a manner recovered.

[15] A Perſon by long watching conſumes a great Part of the moſt ſubtle Humours, ſuch as are adapted to diſtend the moſt minute Tubuli of the Nerves; but then during the ſpace of eight Hours Sleep, there is little or no Diſpendium or Loſs of theſe Particles; but in the mean time a Heat diffuſed through the Body, like that of a ſitting Hen, reſtores the ſame quantity of the like ſubtle Humours;

mours; and therefore Sleep is neceſſary in proportion to Exerciſe (§. 594.). But when Sleep is over long continued, the Muſcles by too much Reſt become unfit for future Action, and the whole Body becomes dull.

§. 598. Every Part being thus recruited by Sleep, there will be again an *Aptitude* [1] in the Body to Vigilance, and an Indiſpoſition to ſleep; ſo that an exciting Cauſe approaching the Perſon will wake again.

[1] Vigilance therefore does not always follow Sleep as a neceſſary Conſequence (§. 590.); only the Stock of Spirits is recruited, and if any ſtimulating or exciting Cauſe approaches, the Perſon will continually awake. A Comic Author in a particular Scene introduces with *Aurora* the returning Labour and Cares of the Day, which are abhorred by the Sun, whoſe powerful Rays excite thoſe who are half diſeaſed and in Pain and calls them to the Plough, when they would have found a Cure for all their Difficulties if they were but permitted to ſleep a little longer. Sleep itſelf therefore does not awake the Patient, but it ſupplies or provides proper Matter in due quantity and quality ſufficient to render the Perſon vigilant when he is awaked by ſome exciting Cauſe. When a Child awakes it is uſually convulſed, ſtretches all its Limbs, and in a little time after rubs and opens its Eye-lids, gapes or yawns to accelerate the Blood through the Lungs into the left Ventricle of the Heart; and then all the Muſcles are relaxed and in a manner opened, by which they are fitted to be ſupplied with Spirits ſent from the Brain, which compleats the Vigilance or Awaking.

§. 599. From hence we may be able to give a Reaſon, why a Perſon cannot Sleep with his Head hot and his Feet *cold* [1]?

Why *Drunkenneſs* [2] follows from ſpirituous Liquors, and afterwards Sleep?

From whence proceed *Dreams* [3], and from whence walking in the Sleep?

Why after a laudable Sleep confined within the ſpace of eight Hours, the *Perſpiration* [4] is twice as large as it would have been if the ſame time had been ſpent in Vigilance?

Whence it is that by ſleeping *too long* [5] the Head becomes heavy, the Senſes dull, the Memory weak, the Body cold, phlegmatic, fat, heavy, or unactive and weak, with an Inaptitude in the Muſcles to Motion, and an *imperfect* [6] Perſpiration?

From whence Sleep *long continued* [7] may ſupport Life for a conſiderable time, without *Food* [8] or Drink?

Whence it is that after a laudable Sleep all the Muſcles are uſually *expanded* [9], *yawning* [10] is repeated, and the Sharpneſs of the Judgment, Activity of the Muſcles and Strength of the Nerves return?

Whence it is that a *Fœtus* [11] ſleeps always, that *Children* [12] ſleep often, and growing or young People more than adult or old People?

Laſtly, for what end thoſe who are *recovering* [13] from violent Diſeaſes ſleep much longer than when they are perfectly well? Why we are ſleepy after *Meals* [14], and active *before* [15], and why we have ſo large a *Brain* [16]?

[1] They who go to bed with their Feet cold and their Head hot in Winter, never fall into a Sleep until their Feet begin to be warm. There is a Hiſtory relating to this Subject given us by *Carolus Piſo*, who when a Lad ſtudying with his Companions in a cold Place ſeveral Days, himſelf and all of them fell into violent Catarrhs and Diſorders of the Head; namely, becauſe the Circulation of the Blood in the Head was increaſed too much by Vigilance and Meditation, while its Motion thro' the Feet was impeded by the external Cold, ſo that the Blood was derived from the contracted Veſſels of the Feet towards the relaxed Veſſels of the Head; and therefore Sleep could not follow, which ſuppoſes an Equability in the Circulation of the Blood.

[2] Of Drunkenneſs there are three Degrees, in the firſt of which there is a great Readineſs to all the Functions of human Life, even greater than in a healthy Perſon, and accompanied with extreme Gladneſs. Thus *Horace:*

Tu ſpem reducis mentibus anxiis
Vireſque, & addis cornua pauperi,
Poſt te neque iratos trementi
Regum apices, neque militum arma.
Lib. III. cap. 22.

The ſecond Degree is a kind of Delirium which increaſes imperceptibly, till at length the Will loſes its Influence upon the Limbs, Tongue, and all the other Actions proper to human Life. The laſt is a dead Sleep next to an Apoplexy, in which the whole Body continues immoveable, and does not perceive even the greateſt Injuries. This follows from the Spirit of Wine mixing with the Blood, and as a Body extremely volatile ſoon flying to the Head more than any other Part, where it

it expands the cortical Subſtance more than the Reſiſtance of the Medulla is capable of ſupporting. For ſuch is the Nature of inflammable Spirits that they neither coagulate the Blood in the Veſſels, nor do they arrive into the Veſſels with their full Power, but inſinuating into the ſmalleſt Veſſels, they diſturb the Motion of the Humours, which cauſes a Delirium. Hence alſo Sleep follows from the Uſe of the moſt volatile Medicines. From plentifully drinking of inflammable Spirits, a continual Sleep follows, which hardly continues longer than an Hour; for Alcohol powerfully inebriates, becauſe it is ſo volatile as to fly into the Air with the leaſt degree of Heat; and it appears by chirurgical Experiments, that by touching the naked Nerves they become inſenſible therewith; and why may it not produce the ſame Effect when taken by the Mouth internally? On the contrary, the drinking of the ſtrongeſt Ale, ſuch as Mum in a large quantity, occaſions a Sleep of long ſtanding, perhaps of two or three Days; namely, becauſe the ſpirituous Particles inviſcated in the Ale expand themſelves more ſlowly. But Liquors which have not been fermented do not inebriate, becauſe their Particles are too groſs to aſcend or fly up to the Head.

* When any Part of the Medulla of the Brain is empty and collapſed, while another Part remains free and diſtended with Spirits, the Perſon dreams; and therefore dreaming is a kind of half Vigilance or imperfect Sleep. Hence we need not ſo much wonder at thoſe who walk in their Sleep, for when that Part of the Brain remains free which appertains to muſcular Motion, the Spirits will then be as neceſſarily detached to the Muſcles by an internal Cauſe without a Conſciouſneſs of the Mind, as in a State of Vigilance; much in the ſame manner as

we walk in deep Meditation, without being at all conſcious that we do walk. Thoſe who walk in their Sleep therefore are but half aſleep. From hence we may underſtand why a Perſon will ſleep ſound who has been much tired, unleſs the Fatigue has been ſuch as to produce Pain in the Nerves, which impedes Sleep and intermixes the State of Vigilance with that of ſleeping; and why thoſe are inclined to ſleep who do not ſufficiently exerciſe the Body in proportion as they meditate, as alſo when they have lain too long a-bed in a Morning. But concerning Sleep from other leſs frequent Cauſes, as from the Atra-bilis, it is not the proper Buſineſs of this Place.

4 The concoctive Powers of the human Body by which our Humours are attenuated, are equally applied to all the crude Humours in the Body. Nor ought the Body to be exerciſed after Meals, in order to preſerve Health, as I was formerly perſuaded with the common Opinion; for this is repugnant to Nature, who inclines all Animals to ſleep after Meals, at which time the Body cannot well be exerciſed without ſome Uneaſineſs. But Exerciſe of Body is the beſt before Meals, upon an empty Stomach, according to the ancient Advice of *Leonidas*, who had the Care of *Alexander* in his Youth. But even that Perſpiration is greater in Sleep, is demonſtrated from the Obſervations of *Sanctorius*. If of two healthy People one ſits ſtill at the Table or walks about the whole time, while the other ſleeps three Hours in a Bed, by weighing both of them afterwards, the Perſon who has been ſleeping will be found much lighter than the other; becauſe the Skin of the latter has been kept continually warm and lax while the other has been cold; even though one cannot be able to ſit ſtill without uſing animal Motion.

Since

[5] Since we demonſtrated that Sleep aroſe from a Reſt or Deficiency in the Spirits, which are to be applied to the Origin of the Nerves, we thence underſtand that the muſcular Fibres during Sleep are ſcarcely diſtended; they will therefore be contracted very ſtrongly from their own inactive Power, ſo that they cannot be eaſily on a ſudden diſtended and moved by the nervous Juice. So long therefore the Fibres reſt and become very unfit for Motion, whence the reſt of the Symptoms follow as before-mentioned. The Huſbandman cannot paſs one idle Hour without ſleeping; and therefore if he was to ſpend all the Holidays in ſleeping, he would become weak and incapable of his Buſineſs, unleſs he exerciſed himſelf with ſome rough Play, as that of the Ball or the like. One who has been ſleeping ten Hours will be quite dull all the reſt of the Day, unleſs the Body is exerciſed after Noon; for by that means Alacrity and Activity may be recovered.

[6] Becauſe the ſmaller Veſſels are indeed filled, but they want Motion to propel the Humours through the Extremities of thoſe Veſſels by the Preſſure of the Muſcles. But if Sleep is continued longer than uſual, then the Fat being accumulated buries and compreſſes the ſmaller Veſſels, ſo as to prove another Cauſe retarding the Motion of the Humours, and ſuppreſſing the Perſpiration.

[7] I cannot give Credit to thoſe over ridiculous Chriſtians, who relate the Story of the ſeven Sleepers for true. Yet I believe it poſſible for a Perſon to live a long time without Food or Drink, provided only the Circulation is continued through the larger ſanguiferous and ſerous Veſſels. After five Hours Sleep the Humours are derived into the cutaneous Veſſels, and a plentiful Perſpiration is begun; but when the Perſpiration is over, the cuta-

neous Veſſels contract and ſhut up their Pores; whence a Perſon may ſurvive a long time in that manner, till he is at length awakened by a ſlow and pleaſing Conſumption (§. 597.)

[8] Thus in the Species of Erucæ or Caterpillars among Inſects, as well as in other Animals which paſs the Winter in Sleep, they are ſupported without Food. The Cauſe of ſo long a Sleep in theſe Animals may be from the great Viſcidity of their Humours, which are not propelled and exhaled from the Surface of the Body, but are only drove by a little weak Heart to the ſmall Brain, while a ſmall Portion circulates through the Lungs. Hence there is but little waſte of the Humours, and the Animal continues a long time in the ſame State; but at the Approach of any Heat whether artificial, (in the midſt of Winter) or natural in the Spring, the Humours will be expanded and the Lungs filled; ſo that the Animal becoming more active will now require Food. But the Humours are prevented from Putrifaction during their Reſt, by the Cold, as alſo by the Excluſion of the Air. Even by excluding the Air a human Fœtus may be preſerved for many Years uncorrupted. In other Animals that ſleep in the cold of the Winter, which are very numerous, the Reaſon is different. In thoſe who are aſleep the Spirits are not conſumed as in Vigilance, and the Humours are derived into ſmaller Veſſels, through which they are very hardly moved forward; but then all the Oil or Fat is poured out round the Sides of the Veſſels, ſo that the Animal is as it were covered over with an oily Cruſt, by which it is preſerved from corrupting during the firſt Stage of Sleep. But when the firſt Stage of Sleep is over, as, for Example, when the Animal ſleeps twenty-four Hours when it is uſed to ſleep but ten; from that time the Motion of the Blood

Blood continually grows leſs and leſs, ſo that at laſt one may doubt whether it has any Motion at all. *Lewenhoec* received ſome Bats in the Winter which were found concealed behind ſome Hangings, but could not perceive any Motion in their Blood; but by bringing them to the Fire, their Blood began to move very ſwiftly. This is ſtill more evident in Frogs, which I have found lying ſtill in the Winter-time as if dead, inſomuch that the Body would not move even by cutting off a Leg; but by expoſing them to the Sun they ſoon recovered their former Vivacity, ſo that I could hear them croaking in the Glaſs. Hence it is that theſe kinds of Animals always covet to be in the Sun which gives them new Life. But if ſuch an Animal is not revived by any Heat, either of the Sun or of ſome other Body, the Blood at length moves ſo ſlowly as to become acrid even by Reſt; and diſſolving the adjacent Drops of Oil after Diſſolution, they return with the Blood of the next adjacent Veins.

[9] In profound Sleep the Spirits, which are the Authors of all the voluntary Motions, are at reſt, as well in their Origin the Brain and Nerves, as in the Muſcles. But when an Animal awakes the Spirits begin to move, and the Mind bends its Force towards the Parts to be moved, whence generally follows an equable Inflection of the Muſcles.

[10] Yawning is a deep Inſpiration, by which the Courſe of the Blood is accelerated through the Lungs, whence it paſſes moſt ſwiftly into the left Ventricle of the Heart, and from thence it returns with a greater Preſſure to the Brain and Cerebellum by the Arteries.

[11] The moſt healthy Fœtus ſometimes ſtartles or ſtretches itſelf at ſmall Intervals in the Womb of its Mother, but all the reſt of the time of its

inhabiting in that Part, it continues at reſt as if it were dead; and therefore it is very probable that it is then ſleeping. But it is credible, that when the prepared Chyle is poured into the Mother's Blood in large quantities, as muſt happen towards the Morning or any other long Interval after a Meal, then the Fœtus uſually beſtirs itſelf. But in Sleep Nutrition is the greateſt, and the Attrition or Deſtruction of the Parts little or nothing; and therefore the Fœtus grows more in the nine Months of its Geſtation, than it ever does afterwards within the ſame ſpace of time, till it becomes an Adult; for in this ſhort time it grows up from an inviſible Point, ſupplied from the Semen maſculinum, even to the Weight of eight, nine or thirteen Pounds (§. 675.); but ſuch an Increaſe is never afterwards performed from the Birth, becauſe the Sleep and Nutrition are both leſs. But the Cauſe of ſo long Sleep in the Fœtus, is the prevailing Force of the Heart over the Reſiſtance of the Humours and Veſſels; but the Action of the Heart is vital, and therefore it overpowers the animal Actions; and ſo long does Sleep prevail over Vigilance. The Fœtus, as far as we can tell, has no Ideas, nor has the new-born Infant any other than that of Pleaſure and Pain; but in this early Stage of Life the Body receives its greateſt Increaſe and Growth, which leſſens as the Brain is more exerciſed.

[12] Children who only awake when they want to be ſuckled, ſleep almoſt all the reſt of the time. But in adult People the Body is only maintained as it were in the ſame State for the ſame Reaſon.

[13] In all acute Diſeaſes there are always tedious Watchings, unleſs the Brain itſelf is affected. I have ſeen thouſands of young People in the Small-Pox, Phrenzy, ardent Fevers, Pleuriſies, *&c.* who have not ſlept Night nor Day for a whole Week toge-

together; but when they have been recovered, their Body has been lighter by one third Part of its Weight, ſo that thoſe who have been very fat have been reduced almoſt like Skeletons. And therefore theſe Watchings with Sweats or other Evacuations have in this manner waſted the Body. So long as the Diſorder rages the Patient can riſe up and move his Body, but when the Diſorder is off he cannot ſupport himſelf, but ſleeps Night and Day; and in this Caſe the Patient's Friends, very often without Reaſon, are afraid of an Apoplexy; for nothing more powerfully recruits thoſe who are recovering than Sleep, if at the ſame time they are ſupplied frequently with ſmall quantities of laudable Nouriſhment.

[14] The Drowſineſs which follows after a Meal is uſually aſcribed to the crude Chyle, which being conveyed to the Brain with the Blood, impedes the Motion both of that Fluid and the Spirits thence ſeparated. But this Dulneſs does not follow when we uſe Food of eaſy Digeſtion, from whence much Chyle is prepared; but it follows chiefly from great quantities of hard Aliments diſtending the Stomach, and increaſing the Circulation upward, by compreſſing the Aorta; and retarding the Courſe of the Blood downward. When we have eat too large a Supper we frequently paſs the whole Night reſtleſs or with a half kind of Sleep, which renders us dull the next Day. If now we evacuate from the Stomach the offending Matter, we ſoon become chearful and eaſy. Nor ought it to be objected that from this greater Derivation of Blood to the Brain, more Spirits ought to be ſeparated, and that therefore a Chearfulneſs ought to follow inſtead of Dulneſs; for the ſanguiferous Arteries being too much diſtended compreſs and obſtruct the other ſmaller Arteries.

We

[15] We are the moſt active a conſiderable time after a Meal, as the Spirits then abound moſt; but this Abundance of the Spirits does not follow from the laſt Meal, but from a long and ſucceſſive Series of Changes, by which the Serum of the Blood is attenuated into more ſubtle Juices.

[16] We are furniſhed with ſo large a Brain, becauſe that Part in Animals is proportioned to their Ingenuity; and therefore the Brain is largeſt in Man, and next after him it is largeſt in Apes, Dogs, *&c.* in proportion to the reſt of the Body. It is not eaſy to meet with a Perſon fooliſh from his Birth, whoſe Brain has not been altered from its natural or ſpheroidical Figure. In general, the larger the Brain the more ingenious is the Animal, and the larger the Cerebellum the ſtronger the Animal; and therefore the ſtrongeſt Animals have but a ſmall Brain.

§. 600. But the Reaſon why the Heart is not relaxed and *inactive* [1] during Sleep like the other Muſcles (§. 590. N°. 3.), but on the contrary acts more ſtrongly, contracting and dilating alternately, will appear evident if we attend to the following Particulars: 1. The Difference betwixt the *Brain* [2] and Cerebellum, the former being *ſoft* [3], furniſhed with *Cavities* [4], and encompaſſed with venous *Sinus's* [5] of different Courſes, being capable of Expanſion and Compreſſion, and being likewiſe ſpread externally with Circles of the larger Arteries; but the Cerebellum is more ſolid and *compact* [6], has no Cavities, nor is it preſſed or encompaſſed by any venous Sinus's, being incapable either of *Expanſion* [7] or Compreſſion, only furniſhed with ſmall Arteries and Veins

like

like the *reſt* [8] of the Brain. 2. That the *cardiac* [9] Nerves derive their Origin from the Cerebellum only. 3. That the *coronary Arteaies* [10] of the Heart are filled and emptied at oppoſite times with thoſe of all the other Arteries in the Body; and that the like is alſo true of the coronary Veins. 4. That the Ventricles of the Heart are filled at the ſame time with the coronary Veſſels. 5. That the Auricles and Ventricles of the Heart are filled and emptied, contracted and relaxed alternately. From all theſe Conſiderations it will appear, that the Cauſes of the Heart's Contraction are continually renewed and deſtroyed, acting, and ceaſing from Action. But whether or no the vital Spirits of the Cerebellum are more *tenacious* [11] and durable than the animal Spirits of the Brain, muſt ſtill remain a Queſtion? But why does the *periſtaltic* Motion alſo never ceaſe?

[1] We come now to a very difficult Queſtion, namely, why the Muſcles of the Heart and its Auricles, the venous Sinus's, with the Arteries, Diaphragm, thoſe of the Abdomen with the intercoſtal Muſcles; and laſtly, the Muſcles for the periſtaltic Motion of the Inteſtines never ceaſe to act in Sleep, at which time all the other Muſcles in the Body are relaxed; but on the contrary, they are obſerved to act more powerfully than during the time of Vigilance (§. 590. N°. 5, 6, 7.). This Queſtion has been aimed at in all Ages, nor yet has it been ſolved ſince the time of *Harvey*, for want of ſufficient Attention and regard to the *Harvean* Demonſtrations.

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[2] The wiſe Creator has made the Cerebellum different from the Brain. We ſaid before that the Brain in Man is much larger in proportion than in other Animals, who have this Part leſs in proportion as they are leſs human in their Faculties, as they perform fewer of the animal Functions, as they are furniſhed with Senſes leſs acute, and are leſs ready for the Performance of voluntary Motions; in a word, as they approach nearer to a vegetable Nature. In the Skull of a Whale, preſerved here at *Leyden*, the Cavity for holding the Brain will hardly receive one's Fiſt. But in proportion as theſe Animals have a leſs Brain, the Cerebellum is much larger. So that in Fiſh the Cerebellum is exceeding large, and the Brain very ſmall in proportion to the reſt of the Body.

[3] The Brain being ſofter than the Cerebellum, is placed above the latter, and ſuſtained by a Proceſs of the Dura Mater four times thicker than the reſt of that Membrane, being ſeparated in the middle by a Proceſs from thence continued and called the Falx.

[4] By theſe Cavities the whole Brain may be taken for a Plane convoluted into an Arch intercepting a Part in its middle, from whence all the Nerves ariſe (§. 272.). In theſe Cavities are placed the wonderful Plexus Choroides. The anterior Ventricles ſeparate the ſuperior from the inferior Medulla of the Brain; and the third Ventricle in the Medulla itſelf ſeparates that from the Medulla oblongata. All theſe Cavities may be more or leſs filled or emptied with Blood and Humours, ſo as to render the Brain more free and fit or unfit for its Office.

[5] Theſe Sinus's are capable of being filled more at one time than at another; for all thoſe Cauſes which accelerate the Motion of the venal Blood, may

may alſo occaſion a Turgeſcence of the Sinus's in the Dura Mater, which may again contract themſelves by their proper Fibres: but all the Sinus's are placed round the Brain, but none of them round the Cerebellum; and therefore the Action which reſults from the different State of the Sinus's is impreſſed upon the Brain only, where the Secretion and Courſe of the Spirits may be interrupted without cauſing any Change in the Cerebellum.

[6] Even the Medulla of the Cerebellum ariſes from its moſt compact Part, whereas in the Brain, the Nerves ariſe from the middle of its Cavity; but in the Cerebellum the Cortex is ſpread upon the Medulla without intercepting any Cavity or Interval; for the fourth Ventricle which is a ſmall Notch betwixt the Medulla oblongata and that of the Cerebellum can be of ſmall moment: but from the middle of the inveſting Cortex the Medulla ariſes, and by a perpendicular Inciſion appears like the Branches of a Tree, being at length collected into the four Trunks which are inſerted into four diſtinct Parts of the Medulla oblongata; and therefore the Cerebellum continues in the ſame State without Alteration during Life, which the Brain does not. On the contrary, the Brain may be expanded and compreſſed, or collapſe and be relaxed by reaſon of the Cavities placed in the middle of its Subſtance, and into which the Blood may be more copiouſly derived, *&c.* But any Humour collected in the Cavity of any of the Ventricles in the Brain produces Sleepineſs firſt, and then a Lethargy or Apoplexy; the like of which cannot take place in the Cerebellum.

[7] The Cerebellum is ſo ſeated in the bony Caſe of the Skull, that it is defended above by a moſt ſtrong Proceſs of the Dura Mater, below by the Occiput, betwixt which on all Sides there is a looſe

looſe and free Space. The Proceſs of the Dura Mater ſpread over the Cerebellum is ſtretched tight like the Parchment of a Drum, ſo as to re-act againſt any Force. Externally the Cerebellum is defended by the Occiput, covered in its poſterior and lower Part with the ſcaleni, complexi, recti and oblique Muſcles of the Head, ſo that a Blow or Injury cannot penetrate to the Cerebellum, but through the Brain or through theſe Muſcles.

[8] In the Cerebellum there are no Sinus's, only ſimple Arteries and Veins ſpread within the Pia Mater and diſtributed upon the Cerebellum. But the Cerebellum is not inveſted by the Dura Mater; and therefore the Motion or Circulation of the Humours through the Arteries and Veins in this Part is performed more equably. Add to this, that the Cerebellum receives its Blood principally from the vertebral Arteries, which immediately after their Origin are received into a Canal running through the Vertebræ of the Neck on each Side, in which they are ſecured till they enter into the Cranium; ſo that they cannot be compreſſed like the Carotids (§. 232.).

[9] I make not the leaſt Doubt but that moſt Parts of the human Body receive their Nerves from the Brain, but that the Nerves for the Motion of the Heart are derived only from the Cerebellum; and this is confirmed by anatomical Experiments made by the excellent *Du Verney*, who has taught us, 1. That the Brain being deſtroyed or rendered incapable of its Office, the Heart nevertheleſs continues to move, which makes it evident that the Motion of the Heart does not depend upon the Brain. 2. On the contrary, the Cerebellum being deſtroyed or rendered incapable of its Office, the Motion of the Heart is always ſuppreſſed; and therefore the Motion of the Heart reſults not from the Brain but from the Cerebellum:

lum: but ſince the Cerebellum can ſupply nothing to the Heart but Nerves, therefore it is evident that the Nerves of the Heart are derived from the Cerebellum. It could never yet indeed be demonſtrated anatomically, that any Nerve ariſes from the Cerebellum only, as the olfactory Nerves are obſerved to ariſe only from the Brain: for all the Nerves beſides are propagated from the Medulla oblongata, which is formed by the Union of the medullary Peduncles or Footſtalks both of the Brain and Cerebellum. But it is ſufficient to convince us of this Truth, if we conſider that Experiments demonſtrate that Injuries of the Brain deſtroy the voluntary Motions, but do not in the leaſt deſtroy the Motion of the Heart, which cannot be affected or changed by ſo ſlight a Cauſe as is capable of producing Sleep in the Brain: but when the Cerebellum is injured the Heart itſelf ceaſes to move, that is to ſay, the Animal expires; for Surgeons well know how much more fatal is an Apoplexy ariſing from a Compreſſion of the ſpinal Medulla, than from an Injury of the Brain only.

10 The Force of the Arteries is nearly equal to that of the Heart, for let but the Heart ceaſe to move by ſuſpending its muſcular Force, and the Blood itſelf will alſo ceaſe to move, except the Motion derived from the Contraction of the Veſſels is increaſed by the ſupervening Cold; whence the Blood is forced from the Extremities towards the right Auricle and Ventricle of the Heart. The Motion of the Blood in the Arteries is continually deſtroyed, except what is derived from the natural Contraction of the Arteries, by which they protrude the Blood into the leſs reſiſting Veins; which Action of them is likewiſe increaſed by the Cold ſupervening Death. From this Obſervation we may be able to explain, why in acute Diſeaſes all the

the Blood is found in the Arteries while the Veins appear empty? and why on the contrary in a healthy Perſon who has been lately ſtrangled or drowned, the Blood is found two or three Days after Death to be all collected in the Veins, while the Arteries are quite empty. Namely, in acute Diſeaſes the Arteries cannot overcome the Reſiſtance of the viſcid and congealed Blood, which has been exhauſted of its moſt fluid Parts (§. 260, 261.): But when the Blood retains its fluid State, it is eaſily propelled by the wonderful Action of the Arteries in ſudden Deaths into the leſs reſiſting Veins; but the Action of the Lungs ceaſing, the Blood cannot paſs into the left Ventricle, whence the Arteries will continue to protrude their Blood without receiving their uſual Supply; and therefore the Blood will be accumulated chiefly in the large Trunks of the Veins, in the right Auricle and Ventricle of the Heart, and in the pulmonary Artery. If we conſider the Motion of the Heart in its natural State, we find that the Blood is propelled from its left Ventricle from no other Cauſe than a convulſive Spaſm or muſcular Contraction, the Force of which is ſufficient to propel the Blood from the Cavity of its left Ventricle into the Aorta; but this propelling Force is not greater than to dilate the Aorta to ſuch a degree as to give room for the Reception of its expelled Blood (§. 218.). But the moment after this Contraction of the Heart, the Blood contained in its own Veſſels being expelled cauſes that Muſcle to look pale and bloodleſs. But the Blood expelled from the Heart neither ſtagnates nor is urged beyond the Heart, which being relaxed no longer exerts any Force upon that Fluid. But while the Heart is filling, and before a ſecond Contraction of it follows, all the Blood received from the Heart by

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the Aorta, is by its contractile Force protruded from its Cavity and Branches into the Veins; ſo that a like quantity of Blood is conveyed from the Arteries into the Veins in the ſame time, as the Blood which is thrown from the left Ventricle into the Aorta; whence the Force of the Arteries appears to be equal with that of the Heart, which exerts no other Action but that by which it expels the Blood into the dilated Aorta. But the coronary Arteries which are diſtributed through the muſcular Fabric of the Heart, are empty when that Muſcle is in its Contraction; and conſequently the inſtant after this Contraction, the Blood which is propelled every way by the Aorta, will return back towards the Valves and fill the coronary Arteries with the ſame Force as it is protruded by the Aorta into other Parts. But immediately before the Heart are placed venous Auricles, into which the coronary Veins convey all their Blood. But when the Heart propels its Blood into the Arteries, there is a greater quantity of that Fluid contained in the Cavity of theſe Veins, and therefore what is redundant flows from the Arteries into the Veins; ſo that this acceſſary Force from the coronary Arteries protrudes the venal Blood through the correſponding Veins into the Auricles, from whence the next moment the Blood paſſes into the relaxed right and left Ventricle. Laſtly, when the Ventricles of the Heart propel their contained Blood, that Blood drives forward all the reſt contained in the Arteries, namely, in the Aorta and pulmonary Artery: and theſe arterial Trunks being therefore diſtended at the ſame time, muſt neceſſarily compreſs the Nerves which paſs into the Heart betwixt them (§. 409.); and the Nerves of the Heart being thus compreſſed during its Contraction, it muſt neceſſarily become paralytic

or relaxed in the next inſtant. But the moment after this Diſtenſion of the arterial Trunks, they contract themſelves to a leſs Diameter, whence the cardiac Nerves being ſet at liberty the Spirits have a free Courſe into that Muſcle. Hence it is that the Heart cannot ceaſe to move even in Sleep; for ſo ſoon as the Heart is relaxed, the coronary Arteries are likewiſe relaxed at the ſame inſtant, and therefore the Blood meeting with no Reſiſtance will be freely preſſed into them by the Aorta. But at the ſame time that the coronary Arteries are thus filled and the Ventricles relaxed, the venous Sinus's contract and pour their Blood into the former, while at the ſame time the Spirits of the Cerebellum flow freely through the Nerves, betwixt the large Arteries which are now contracting themſelves. Thus the Heart cannot ceaſe to move, ſince the three Cauſes of its Contraction are perpetually renewed, namely, the Repletion of its Cavities with Blood, a free Influx of Spirits by the Nerves, and of Blood by the coronary Arteries into its muſcular Fabric. But if the coronary Arteries were filled at the ſame time with the other Arteries of the Body, in that caſe the Heart would ceaſe to move during the time of Sleep. The beautiful Contrivance or Mechaniſm demonſtrable in this Fabric of the Heart, ſo much affected the Mind of the celebrated *Pitcairn*, that he pronounced, that if we are ignorant of all other Particulars and could ſee only the Fabric of the Heart with its Auricles, Sinus's and Arteries, we ſhould plainly perceive that theſe Bodies were not made for themſelves, but for ſome other Uſes without or diſtant from them, and that they could not be the Authors of themſelves, as *Carteſius* would have us to believe.

Thus

[11] Thus indeed it would ſeem to be with the Spirits of the Cerebellum, ſince the Veſſels of that Part are ſtronger and thicker than the Veſſels of the Brain. But Nature has given every kind of Veſſels a different Fluid to be conveyed agreeable to their Texture. It would alſo ſeem that the animal Spirits require a longer Preparation than the vital Spirits, ſince by general Laws of Nature in the human Body, the thinneſt Humours are always derived from thoſe which are next in Succeſſion of a more groſs Texture. If now it can be demonſtrated that the animal Spirits are generated as ſlow again as the vital, we ſhall be furniſhed with a manifeſt Reaſon, why the animal Actions ceaſe during one half of Life, when the Heart and natural Powers always continue to perform their Office. For in the firſt place, there may be a Deficiency of Matter for the Formation of Spirits in the Brain, when at the ſame time the Cerebellum may be well enough ſupplied. Secondly, the more ſenſible Spirits of the Brain may be affected and exhauſted, while the more permanent Spirits of the Cerebellum continue undiſturbed.

[12] Why theſe involuntary Muſcles do not ceaſe to act during the time of Sleep, namely, thoſe which carry on the periſtaltic Motion, I muſt confeſs myſelf ignorant, and reſolve the Cauſe into the Omnipotent Power of the Creator, who has thus wonderfully formed our whole Body at once. Our mechanical Learning teaches us to explain the Nature and Action of Machines, which have been made by a ſucceſſive Addition of Parts. But a Machine which is produced at one and the ſame inſtant of time, cannot be perfectly explained by thoſe mechanical Rules, which are ſcarce ſufficient to acquaint us with the Nature of artificial, and much leſs with the Nature of created Engines.

But nevertheleſs theſe Motions, which we are not able to explain, do really exiſt in the Body. I have often ſeen the Stomach and Inteſtines taken out of a living Animal creep in my Hand after they were extracted from the Body, continuing to move as if they ſtill remained in their Situations. If the Thorax of a living Dog is inſtantly opened by a ſharp Scalpel, and the Heart ſuddenly cut out, upon throwing it into a Baſon full of cold Water, it will jump out of the ſame as if it was a living Animal, and continue to beat more languidly for a long time after. The Heart being taken out of a large Eel, will continue its Motion of contracting and dilating for ſeveral whole Hours together; and even when it ſtops it may be again excited into Motion by pouring on warm Water. From hence therefore it is evident, that it is not in the Power of human Intellect to explain all things at once, nor even to explain any thing but by Parts, the Glory of which is to be aſcribed only to that Being who made all things at once. The Lungs which continue idle in the Fœtus, were nevertheleſs created and diſpoſed in the ſame manner as they afterwards appear to us, that they might dilate and take in the Air at the firſt moment of Life; and that the Lungs and other Parts ſhould be thus formed in the firſt Delineation of the human Body, before the Action could follow from the Fabric, muſt be altogether the Contrivance of the Omnipotent Hand. The ſame is alſo true with reſpect to the Foramen ovale, the Canalis arterioſus and venoſus, with the umbilical Arteries and Veins, the Urachus, and other Parts.

Of Reſpiration.

Of RESPIRATION [1].

§. 601. WHAT Reſpiration is or how it is performed, and why it *continues* [2] without the Influence of the Mind, will be evident from what follows; for the Order of our Syſtem requires us in the next place to examine into this Action, which although we ſee performed more than any other, is nevertheleſs difficult to underſtand; chiefly becauſe is is an Action *partly* [3] vital or ſpontaneous and partly voluntary, and in ſome meaſure becauſe of the *numerous* [4] Organs which are employed in the Exerciſe of this Function; which we are therefore to diveſtigate with Care and Attention, as may be beſt done by conſidering its ſeveral Appearances and Organs.

[1] Reſpiration is an alternate Entrance and Expulſion of the ambient Air into and from the Lungs, by the Wind-pipe and Air-veſſels of that Viſcus; in which Action we diſtinguiſh four Periods: The firſt is a Derivation of the Air into the expanded Air-veſſels of the Lungs, namely, into the Larynx, Wind-pipe or Trachea, and its Ramifications the Bronchia, with their Expanſions, the Veſicles of *Malpighi*; Secondly, a Retention of the Air derived into theſe Receptacles, in which it continues ſome time without being either inſpired or expired; Thirdly, the Expulſion of the inſpi-

red and retained Air, from its ſeveral forementioned Receptacles in the Lungs: Fourthly, a ſecondary Reſt of the Lungs after Expiration, in which they continue quieſcent for ſome time without inſpiring or expiring.

[2] This is a difficult Queſtion, not ſolved by any Phyſician or Philoſopher, until Dr. *Havers* firſt laid a Foundation for its Solution, by ſhewing that the Cartilages change their Angles with the Ribs, whoſe Extremities likewiſe recede from each other; whence he demonſtrates that the breadth of the Thorax is increaſed laterally. But even at preſent this Action is not ſufficiently underſtood among ourſelves, notwithſtanding the numerous Experiments which have been made for that Purpoſe.

[3] That Reſpiration is a vital Action, appears from its Continuance in Sleep and in Apoplexies, in which it is rather increaſed, though all the animal Actions are removed. But it is alſo evidently, in part, an animal Action, becauſe we can accelerate and retard it at pleaſure, or take a deep or a ſhort Reſpiration as we pleaſe. But we cannot thus exerciſe the Influence of our Will upon the Heart, which neither moves ſlower nor faſter according to our Inclination; yet are we only to underſtand this ſo as that we cannot immediately by our Will alter the Motion of the Heart; for when we alter Reſpiration by our Will, either by accelerating or retarding the ſame, we can by that means alſo either accelerate or retard the Motion of the Heart as we pleaſe. Even in Reſpiration we muſt confeſs that the animal rather exceeds the vital Power; ſince a Man can kill or ſtrangle himſelf only by a voluntary Retention of the Air. Thus the Slaves of *Angola* from the ſouthern Parts of *Africa*, being weary of their Lives, retain their Breath as they ſtand, until they are ſuffocated; whence

whence we learn, that theſe Slaves are a precarious Merchandiſe, ſince at the leaſt Diſtaſte they deprive themſelves of their Breath, and their Maſter of his Profit.—There are even Inſtances of Children ſuffocated by crying, inſomuch that it is a common Phraſe, for a Child to cry itſelf to death; and there are again other Inſtances of People to be found in Authors, who have been ſuffocated by Laughter. I once ſaw the Reſpiration ſo much obſtructed by a profuſe Laughter, that the jugular Veins ſwelled greatly, the Brain and Cerebellum itſelf beginning to be over-charged with Blood, which if continued might have induced an Apoplexy and Death.

4 Almoſt an infinite Number of Organs conſpire towards the Act of Reſpiration, each of which ought to be in a ſound or natural State for the due Continuance of that Function; even there is hardly the leaſt Part of the Body which has not ſome relation to, or influence upon theſe Organs. Hitherto belong the threefold vaſcular Syſtem of the Lungs, of which its whole Subſtance is compoſed, namely the pulmonary Arteries, which are as it were a Continuation of the right Ventricle of the Heart; the pulmonary Veins, which are in a manner a Production of the left Ventricle of the Heart; laſtly, the Air-veſſels of the Lungs, namely, the cartilaginous Bronchia, and their Expanſions or Veſicles. To theſe add the Thorax, Diaphragm, Abdomen and its Muſcles, the intercoſtal Muſcles, the Ribs and their firm but moveable Articulations; with the Vertebræ, the Sternum and Clavicles, duly ſituated. But beſides theſe, to voluntary Reſpiration belong the Muſculus ſerratus poſticus ſuperior, the Subclavius, the Serratus poſticus inferior, Rhomboides, and every one of the Muſcles moving the Scapula and Ribs; to which add the Flexors of the Neck,

which come into the Aſſiſtance of the former. From this Multiplicity of the Organs, it is evident why ſo few underſtand the Buſineſs of Reſpiration; for moſt Phyſicians can hardly enumerate the Names of thoſe Muſcles which are ſubſervient to this Action; but we know of no other Cauſe of any Action, beſides the Parts themſelves of the human Body, by which the Action is performed, the Fabric of which being unknown, it is not poſſible for one to underſtand their Action. The Clown knows as well as the moſt expert Anatomiſt, that in Reſpiration the Thorax is dilated, and the Abdomen ſwelled out; but it is the Buſineſs of the Phyſician to know what are the Parts of the human Body which perform theſe Motions, which being duly performed make Health, and which being injured conſtitute Diſeaſe. The greateſt Difficulty in the Knowledge of Diſeaſes reſults from the Multiplicity of Organs which concur towards any Action or Function, the whole of which is diſturbed from the Injury of any one particular Part; whence in the mean time it is very difficult to know preciſely, which of the numerous Organs only are injured. If there are a thouſand Cauſes concurring to produce any Functions, and you are unacquainted with but one of them, you cannot be ſaid to perfectly underſtand that Function; nor yet can you reſtore the loſt Health, if that Cauſe only of which you are ignorant ſhould be in fault.

§. 602. The Lungs being ſuſpended in the open Air, which has free Acceſs to them on all Sides, and preſſes upon them every way *equally* [1], in that caſe they always collapſe and contract themſelves into a leſs Space, becoming much ſmaller in Bulk than they were, while

while they remained entire in the Thorax; this we are taught from Anatomy: but this Change is produced chiefly by the Action of the contractile muſcular Fibres, which connect the ſquamoſe Segments of the Bronchia to each other.

[1] Preſſing equally as much upon their internal as upon their external Surface. This Experiment may be eaſily tried in the Body of a Perſon, extinguiſhed in Health by ſudden Death: Firſt remove the Integuments and intercoſtal Muſcles, being careful to avoid wounding the Pleura; and then by applying a Candle, you will ſee through the entire Pleura, that the Cavity of the Thorax is leſs than is commonly believed, being entirely filled with the Lungs, in ſuch a manner that there is not any Air betwixt the Lungs and the Pleura. Since therefore in this State of the Parts, the Air cannot enter into the Cavity of the Thorax, it will be at reſt, and by its Weight preſs the Thorax as well as the Abdomen againſt the Lungs, until the Diaphragm aſcends up to a Line drawn through the middle of the Papillæ of the Breaſts. In the next place ſuddenly perforate the Pleura, and the Air will immediately and continually enter, whence the Lungs on the perforated Side of the Thorax will collapſe. The Cauſe of its Collapſion is this: The Air being admitted through the Wound of the Pleura, is of the ſame Denſity with that admitted into the Cavity of the Lungs by the Mouth, whence the Lungs will be in Equilibrio betwixt the internal Air with which they are filled, and the external Air of the Atmoſphere, which preſſes upon the Thorax without. The Air therefore admitted through the Wound of the Thorax is very improperly ſaid to have compreſſed the Lungs by its Weight; for we know from Hydroſtaticks, that

that every Solid immerged in an homogeneous Fluid, receives no Alteration in its Figure; but in the preſent Caſe it is manifeſt, that the Air admitted into the Bronchia reſiſts, ſo as to prevent the Veſicles from collapſing, with the ſame Force with which they are compreſſed by the Air without. The Cauſe then of the Collapſion of the Lungs is this, namely, in a ſound Body, they are always in a State of Violence, being more expanded by the Air admitted through the Glottis, than they would be, if they were ſuſpended out of the Thorax in the open Air; for the Lungs when in Equilibrio are one third Part leſs than the Cavity of the Thorax, to which they are equal in the living Animal, and than which they are even larger in a State of Inſpiration; ſince they burſt forth thro' a Wound of the Thorax. Therefore the Muſculi meſochondriaci or muſcular Fibres which connect the cartilaginous Segments of the Bronchia, are always endeavouring to contract the Lungs into a leſs compaſs, ſo ſoon as the Air is freely admitted to their external Surface, ſo as to cauſe an Equilibrium betwixt their diſtending the Lungs internally and that compreſſing them externally; for then the Lungs being ſet at liberty from their expanding Force, are contracted into a leſs compaſs, by the Action of the Muſculi meſochondriaci. The Cartilages of the Trachea we know are imperfect or membranous behind; and we alſo know, that the Bronchia and their Ramifications are made up of cartilaginous Rings, connected to each other by whitiſh muſcular Fibres; which Fibres ſuffer themſelves to be expanded by the Powers which dilate the Thorax and Lungs, by which means the expanded Branches of the Bronchia are elongated; but when that dilating Power of the Thorax ceaſes, thoſe muſcular Fibres by their contractile Force, draw the cartilaginous Segments of the Bronchia towards

towards each other, whence they become ſhorter, and conſequently the Lungs contract themſelves by their own proper Force, that is, by the Action of theſe Muſculi meſochondriaci. Hence it follows, that Reſpiration is not properly performed by any Action of the Lungs, which are themſelves paſſive. They are not the Cauſe of Inſpiration, ſince they can exert no other Power than that of contracting themſelves: Nor are they the Cauſe of Expiration, for the Force of the Air ruſhing through the Glottis into the Lungs, is the ſame with the Preſſure of a Column of Water of thirty-three Feet; but ſo great a Preſſure or Weight could not be removed by the Contraction only of the Muſculi meſochondriaci. Since therefore the Lungs are perpetually ſuſtained in a ſort of Vacuum during the Life of the Animal, they will continually yield to the Preſſure of the incumbent Column of Air; that is, they will be perpetually in a State of Inſpiration, unleſs there is an alternate Action of the Cauſes which produce Expiration.

§. 603. If the Lungs thus contracted (§. 602.) are *forcibly* [1] *filled* [2] with Air, inflated by the Glottis, they will be diſtended ſo far as to equal the Magnitude which they had in the entire Thorax, and may be even forced to much exceed that Bulk, as we are taught by Experiments.

[1] This diſtending Force may be determined mathematically thus: Let a Bladder full of Air be faſtened to the Glottis of a living Animal, and let the Bladder be preſſed by Weights gradually increaſed, until the Lungs arrive at a Diſtenſion equal to that which they poſſeſs in the deepeſt Reſpiration, namely, until the Diaphragm is thruſt down ſo low as to form a Plane, or even a Convexity towards the Cavity of the Abdomen.

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[a] In a living Dog, upon which the Experiment before-mentioned has been performed (§. 602.), let the Ribs be broke, and the Lungs by Inflation at the Larynx may be diſtended, not only ſo as to equal, but even to exceed the Cavity of the Thorax, which they filled during the Life of the Animal; the Lungs therefore may be dilated by a Power applied to the internal Surface of the Lungs, while nothing dilates them externally.

§. 604. The ſame Diſtenſion of the Lungs (§. 603.) may be likewiſe performed, if the Air which entered through the Glottis be left in the Lungs; and at the ſame time, that Air or its Preſſure is *removed* [1], which comes in contact with the external Surface of the Lungs, as we are taught by the Air-pump of Mr. *Boyle*.

[1] This Experiment has been frequently repeated, namely, by taking the Lungs of ſome young living Animal without injuring them, and then inſert a Tube furniſhed with a Stopper into the Wind-pipe, after which place the whole Lungs and Wind-pipe in a hollow Glaſs of ſuch a Shape, that the Air may be from thence extracted by adapting the ſame to a Pump, taking care in the mean time to prevent any of the external Air from penetrating into the Cavity of the Glaſs, except through the Tube faſtened to the Lungs. Thus it will be ſeen that the Lungs continue of the ſame Dimenſions, ſo long as they are encompaſſed in the Glaſs by the atmoſpherical Air; and that they will be expanded by blowing into them, as they alſo will be by extracting the Air out of the Cavity of the Glaſs, by which laſt Method they may be diſtended to a much greater degree, than by Inflation with the Mouth.

Mouth. This Experiment may be alſo tried in another manner with a Glaſs in the Shape of a Bell, to the Neck of which the Wind-pipe being faſtened, and an oiled Bladder expanded and fixed over its Baſis, ſo as to be moveable by a String; then by drawing down the Bladder, the included Lungs will dilate, and upon letting the Bladder looſe again, it will by the Air be preſſed into the Glaſs; whence the Lungs will return into their former Dimenſions. For when the Bladder is drawn down, the Air filling the Glaſs is expanded into a greater Space, or becomes rarified, ſo as to be incapable of reſiſting the Preſſure of the external Air, which will therefore deſcend through the Tube into the Wind-pipe and Lungs. Hence then there are evidently two Cauſes which dilate the Lungs. The firſt is a greater Preſſure of the Air, endeavouring to force itſelf into the Wind-pipe and Lungs, than is reſiſted by the external Air placed round the Lungs. The ſecond Cauſe is a ſort of Vacuum made between the Lungs and Sides of the Thorax, while at the ſame time the Air has a free Entrance into the Air-veſſels of the Lungs. The firſt of theſe Cauſes does not act till after Death. For Inſtance, when you open the Wind-pipe of an Animal almoſt ſuffocated by drowning in Water, and force Air into the Lungs by a Syringe, in that caſe the Animal revives; and there is no doubt but the Experiment would ſucceed in the human Species; whence it follows that the Lungs are paſſive in Inſpiration, as they give way to the Force of the external Air coming through the Glottis. We are furniſhed with ſome notable Inſtances of Children lately ſuffocated, who have been reſtored to Life again, after a very ſtrong Man has very forcibly blown Air through their Noſtrils; and there may be always hopes of the

Succeſs

Succeſs of this Experiment, when Death has been lately brought on by ſome Accident, while the Organs remain entire; as for Example, when the Mind has been ſuppreſſed by Grief and profuſe Crying; and it is highly probable that many might be preſerved, who are otherwiſe loſt by Suffocation, if a Tube was inſerted into an Opening in the Wind-pipe. But we are even furniſhed with more ſurpriſing Inſtances of Perſons brought to Life again by blowing Wind through the Anus, as we obſerved under §. 42. N°. 2. In this Experiment, nothing more is produced, than a Preſſure in the Lungs exceeding that of the external Air. —— But the other of the two Cauſes of Reſpiration is natural, namely, a ſort of Vacuum formed by the Dilatation of the Thorax, whence the Lungs are expanded.

§. 605. From hence it is evident, that the Lungs always *endeavour* [1] by their natural Force to contract themſelves in every Point into leſs Dimenſions, than thoſe which they poſſeſs during the time of their Confinement within the entire Thorax; and hence again they appear to be always in a State of Violence or Diſtraction during the Life of the Animal; and therefore they collapſe and ſhrink up into a leſs compaſs when the whole Animal is included in a *Boylean Vacuum* [2].

[1] The Lungs in a living Animal are always more expanded, than they would be if left to themſelves in the open Air, whence it follows that during Life they are in a State of Violence, for ſo we call that State of any Body, which reſults not from the Nature of the Body itſelf, but from ſome other

other Cauſe exiſting without the Body; and on the contrary, we call the natural State that which any Body acquires ſpontaneouſly without the Aſſiſtance of any other. The Lungs therefore in a living Animal are always larger, or expanded into a greater compaſs than they would be if the external Air was admitted into the Cavity of the Thorax. This may be eaſily demonſtrated in the dead Body of any Perſon or other Animal; for you will perceive the Diaphragm preſſed up on all Sides into the Thorax, ſo as to reduce its Cavity and Bulk of the Lungs into the leaſt compaſs: but if in this caſe you perforate the intercoſtal Muſcles, this very ſmall Cavity of the Thorax will of a ſudden be greatly increaſed, and the Lungs will become ſtill ſmaller, contracting themſelves towards the Spine. But in this Caſe nothing more is done but a Reſtitution of the equable Preſſure betwixt the Air entering the Glottis, and that which is now a free Acceſs to the Lungs externally. The Lungs therefore contract themſelves into a ſmaller compaſs by their own innate Force, after they have been extended into a greater Bulk by the Air which entered through the Wind-pipe. But even the Lungs in a living Animal collapſe in the ſame manner, after the external Air is freely admitted into the Cavity of the Thorax; and therefore it follows, that the Lungs are continually endeavouring to contract themſelves into a leſs compaſs, and that they never ſtrive to enlarge themſelves. But how then are the Lungs filled with that Air, againſt which they naturally reſiſt and contract themſelves? We know the Preſſure of the Atmoſphere which impells the Air through the Glottis into the Lungs, is equal to the Preſſure of a Column of Water of thirty-two Feet; but a cubical Foot of Water weighs almoſt ſixty-four Pounds, and therefore the Co-

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lumn preſſing upon the Mouth of the Wind-pipe, exerts a great Weight, which the Muſculi meſochondriaci are not able to reſiſt. But this Weight of the Air is of the laſt Neceſſity to preſerve Life and Health. For we periſh much ſooner in a light Air. Hence we may be able to underſtand the Nature of that Aſthma, in which the contractile Force of the Muſculi meſochondriaci is increaſed to double; for in that caſe the Patient is obliged to pant or breathe ſhort, to expedite the Entrance of the Air into the Lungs. But there is another Species of Aſthma like this, which reſults from a Contraction of the Diaphragm.

[2] That is to ſay, a glaſs Veſſel from whence all the Air has been extracted within the Power of our Machines; for notwithſtanding the Endeavours of our Mechanics, they are not able to procure a perfect Vacuum, but near one thirtieth Part of the Air will remain, whence a Barometer whoſe bottom Part is open to the Vacuum, always remains ſuſpended at ſome ſmall Height, at leaſt in my Experiments. In ſuch a Vacuum therefore the Lungs within the Thorax of an Animal, are not able to fill its Cavity, nor expand themſelves, but collapſe together into a ſmall compaſs, whence the Animal expires in a ſhort time; yet ſo that he may be eaſily revived again upon admitting freſh Air. From hence I infer, that the Lungs are always larger than they would be out of the Thorax, that is, when as great a Preſſure is applied to their external Surface by the Atmoſphere, as that exerts to expand them internally. The Cauſe therefore which keeps the Lungs in a State of Violence, is the Air freely admitted through the Glottis into the Bronchia and Veſicles of the Lungs, while on the other hand, they are not compreſſed by the external Air preſſing upon their Surface; nor can

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the atmoſpherical Air compreſs the Lungs, while they are confined in the Thorax, becauſe of the Reſiſtance which the Sternum, Spine, and arched Ribs afford by their Connection to each other.

§. 606. For in reality there *is no Air* [1] like that of the Atmoſphere, naturally contained in any Part of the Thorax, betwixt the Pleura and the external Membrane of the Lungs throughout their whole Extent; there is therefore nothing to compreſs the Lungs externally but the Diaphragm; in the mean time the Air being always freely admitted through the Glottis, will be continually preſent in the Lungs, which will be therefore always a little more extended by the internal Air, than they are *compreſſed* [2] by the external Air excluded by the Diaphragm, Ribs, Vertebræ, &c. ſo that it cannot enter the Thorax, ſufficient to produce an *Equilibrium* [3].

[1] The Cavity of the Thorax is altogether nothing in the living Animal, nor is there any Cavity naturally exiſting in the Pericardium; for the Air ruſhing into the dilatable Lungs, preſſes them ſo cloſe to the Pleura, that there is no Space left betwixt the internal Face of that Membrane and the external Surface of the Lungs, either filled with Air or containing nothing; for it cannot be a Vacuum becauſe an empty Space having no Reſiſtance, the Air entering the Wind-pipe and Lungs, would continually urge them cloſe to the Ribs, ſo as to occupy that Space. But if there is no Vacuity or empty Space in the Thorax, it is ſtill more evident that it contains no Air. *Helmont*

indeed, who thinks different from the reſt of Mankind, ſays, the Thorax contains Air, which he will have to to be received through the Pores of the Lungs; but we ſhall all along demonſtrate, that there is no ſuch Air contained in the Thorax, and that if any thing interpoſes betwixt the Lungs and Pleura, it is a moiſt Vapour tranſuding thro' each Membrane, and ſerving to prevent them from drying or concreting to each other, as they always do upon being dry, as we conſtantly obſerve where a Pleuriſy has been ſeated; for the Pleura being rendered imperſpirable adheres to its contiguous Lungs. Hence therefore there is neither Cavity in the Heart or Pericardium, but the Space which ſeems to be in theſe Parts in dead Bodies, is owing to the admitted Air. For ſince in the living Animal the Lungs fill the whole Cavity of the Thorax, and ſince the Pericardium contains no elaſtic Air to hinder their Expanſion by the external Air, the Pericardium will be therefore preſſed by them againſt the Heart with ſo great a Force, that nothing can be left between, except the exhaling Moiſture which prevents their Concretion.

[a] The Ribs are formed into Arches, ſo as to keep off the Preſſure of the external Air from the Pleura, which can therefore act only upon the Diaphragm; but this muſcular Partition is connected on all Sides to the Cartilages of the Ribs, before to the Sternum, and behind to the Loins, ſo that it cannot enter into the Thorax beyond the degree which is permitted by its Connection with the Ribs and Sternum. But the external Air compreſſes the Abdomen with the ſame Force with that which is exerted by the internal Air to expand the Lungs; and therefore the Diaphragm muſt from hence be preſſed as much as its Connection

will permit into the Cavity of the Thorax. This may be more eaſily underſtood by conſidering the Diaphragm as a Bladder, whoſe Vertex cannot aſcend any higher than its Baſis permits; but in the Lungs there is always ſome Air equally elaſtic and heavy with that of the Atmoſphere; whence they will be more dilated than compreſſed, becauſe the Diaphragm cannot enter the Thorax with the whole Force which is exerted by the Preſſure of the Atmoſphere upon the Abdomen, whence it cannot equally reſiſt the Air in the Lungs, received into them by the Glottis and Wind-pipe; and this happens, becauſe the Diaphragm is not permitted by its fixed Points to aſcend into the Thorax beyond a Line drawn through the Papillæ of the Breaſts, in which Part we ſee that Wounds inflicted at the time of the moſt violent Expiration, penetrate into the Cavity of the Thorax; and on the other hand, the Deſcent of the Diaphragm is determined by the Reſiſtance of the Mediaſtinum, which ſuſtains the Pericardium, and is largely and firmly connected to the Diaphragm.

[s] This is ſomewhat obſcure and deſerves to be cleared up. The Lungs then left to themſelves, are by the ambient Air reduced into a leſs compaſs than that which they occupied in the Thorax of the dead Animal; but in a dead Body the Diaphragm is preſſed as far into the Thorax as its Connection can poſſibly permit, becauſe the Air having free acceſs preſſes it into the Thorax with a great Force, there being at that time no Reſiſtance from the inſpired Air; whence it is that in a dead Body the Lungs are always very ſmall, and yet do they contract into a much leſs compaſs by admitting the external Air. Even in People who have expired of an Aſcites, when the Water filling the Abdomen has preſſed the Diaphragm upward, ſo

as almoſt to ſuffocate the Patient; even in ſuch Bodies the Lungs contract themſelves into a much ſmaller compaſs, by admitting the external Air through Perforations in the Thorax. The Air therefore preſſing upon the Diaphragm cannot urge the Lungs into ſo ſmall a compaſs as they contract themſelves into in the open Air; and therefore there cannot be an Equilibrium equally produced betwixt the Powers compreſſing the Lungs, and the diſtending Pores of the external Air, entering through the Glottis.

§. 607. This Truth (§. 606.) which is of the utmoſt Conſequence towards the Doctrine of Reſpiration, is moſt evidently demonſtrated from *Anatomy* [1]; from the Production and Increaſe of the *Fœtus* [2] in the Womb, as well as from the Growth of the Infant after the Birth; from inflating the Lungs; from *Wounds* [3] penetrating the Cavity of the Thorax, either in one or both Sides, cauſing a Collapſion of the Lungs, and preventing their Dilatation; but more eſpecially and plainly does it appear from the celebrated Experiments of *Hooke* [4]; as alſo from inſpecting the Diaphragm, while the Thorax remains entire in a dead Body, for the Diaphragm appears hollow towards the Abdomen, being thruſt upwards into the Thorax with a great Force; alſo becauſe the Air being admitted through a Wound into the Cavity of the Thorax, the Diaphragm is immediately relaxed, collapſes downward and recedes from the Thorax, whoſe Cavity is thus enlarged. Finally, the

Truth

Truth of this is demonſtrable to the Eye, through the pellucid Pleura in a living Animal, while the Thorax remains entire, and the other Integuments are removed.

' Anatomy demonſtrates that no Air is contained in the Thorax, whoſe Integuments being removed without opening its Cavity, (as may be moſt commodiouſly performed in a Rabbet, whoſe Pleura is very pellucid;) you will then ſee with the naked Eye that the Pleura comes into contact below with the Diaphragm, laterally with the Lungs, and behind with the Pericardium and Œſophagus. If there was any Air betwixt the Pleura and the Lungs, however ſmall in quantity, it would nevertheleſs occupy a Space ſufficient to ſeparate the Lungs from the Pleura, ſo as to prevent them from coming into contact. Thus alſo in a dead Body, which has been ſuffocated or drowned, there never appears any Diſtance between the Pleura and Lungs, but the Thorax is every where perfectly full.

' There was a time when the Lungs of the Fœtus were no larger than a Grain of Sand; but in a mature Fœtus of nine Months, the Lungs are grown much larger; and yet do not the Lungs of the Fœtus admit any Air before the Birth. This is readily granted by all, and eaſily demonſtrated from the ſpecific Gravity of the Lungs in a Fœtus, which ſink in Water; whereas the Lungs of an Adult never ſink, nor can they be ſo far exhauſted of Air, even by the Pump, as to cauſe them to ſink in Water; hence therefore it follows, that there could be no Air in the Cavity of the Thorax in a Fœtus. Even if Air could enter into the Thorax of a Fœtus, it would be immenſely rarified and expanded, for want of being compreſ-

ſed by the circumjacent external Air; nor would it ever permit the external Air to enter into and expand the Lungs, with that Force which we obſerve at the Birth of the Infant. But after the Birth of the Infant, when it begins to breathe, even then the Air cannot penetrate into the Cavity of the Thorax; ſince the Lungs will ſooner burſt than tranſmit Air through their Subſtance either by Inflation or the Pump. Add to this, that if the Lungs had Pores ſufficient to tranſmit Air into the Thorax, we ſhould not be capable of inflating them; for we ſee among Children, that nothing can perplex them more than when ſome miſchievous Lad having punctured a Bladder, they in vain attempt its Inflation. Nor can Air penetrate the Thorax either through the Diaphragm or any other way; for in no Part of the human Body do we meet with atmoſpherical Air: and therefore it follows that if we can find no Air in the Cavity of the Thorax, either of the Fœtus or of the Infant after Birth, there muſt conſequently be no Air reſident betwixt the Lungs and the Pleura.

* This is an Experiment of *Galen*, who took it from *Herophilus*, who have been alſo followed by *Veſalius*, all of them making their Experiments upon Hogs. Having tied down this noiſy Animal on its Back on a Table, they removed the common Integuments and intercoſtal Muſcles, ſo as to diſcover the Membrane of the Pleura, ſo however as to preſerve it entire, but denudating it ſo far that by the Approach of a Candle, the Lungs might be ſeen through the pellucid Pleura. In this Condition the Animal, who is otherwiſe clamorous enough, roars out violently, and the intent Anatomiſt may ſee the Lungs and Pleura, together with the Diaphragm, coming together into

into contact without any intermediate Space. But if now the Pleura is perforated with a ſharp Scalpel, the Air ſuddenly ruſhes with a kind of Noiſe into the Thorax, ſo as to compreſs the Lungs, and ſtop its Action on that Side, while the Animal continues to breathe with the Lungs contained in the other Side of the Thorax, but as quick again, and with the Loſs of half the Strength of the Voice; ſince the Lungs on the perforated Side of the Thorax are quieſcent. If now again the other Side of the Thorax be perforated, then that half of the Lungs will alſo ceaſe to move, and the Animal inſtantly dies, from an entire Suppreſſion of the Reſpiration. In the ſame manner when in Wounds of the Thorax, the Air paſſes from one Side to the other, Blood being alſo extravaſated on one Side, in that caſe the Surgeon making a Paracenteſis on the intire Side of the Thorax to diſcharge the Blood, the Patient unfortunately expires under his Hands, as being deprived of the Uſe of both Sides of the Lungs. Hence we conclude, that there is no Air naturally contained betwixt the Pleura and the Lungs in a ſound Animal; for if there was the leaſt quantity it would compreſs the Lungs on all Sides in the living Animal, in the ſame manner as it compreſſes them after Death, when it has been admitted through a Wound of the Pleura; for certain it is, that the Elaſticity of the Air is equal to the Weight of the whole Atmoſphere, as we are aſſured from the Experiments of Mr. *Boyle*.

[4] This is indeed a beautiful Experiment, and well adapted to give a true Inſight into the Nature of Reſpiration: even if we had it in our Power to make ſuch Experiments towards explaining all the other Functions of the Body, we could eaſily demonſtrate and expound each of them;

This induſtrious, but melancholy Gentleman, laid before the Royal Society met together, a living Dog tied down upon his Back to a Table, after which he opened the Thorax on each Side inſtantly with one Cut by a ſharp Scalpel, and cutting off the Ribs with a Pair of ſharp Sciſſars, the Lungs appeared collapſed and the Animal ſeemed to be dying. After the Dog ſeemed to be dead, the Integuments of the Throat were divided, and a Tube inſerted into the Wind-pipe, through which, Air being inflated by a Pair of Bellows into the Lungs, the Animal revived; upon continuing to inflate the Lungs, ſo as to keep them at reſt equally diſtended, the Animal again ſeemed to be dying; and again, when the Animal was almoſt dead, by inflating the Lungs with the Bellows, the Dog always revived, opened his Eyes, moved various Muſcles, and the Blood then paſſing thro' the Lungs excited the Heart to renew its Contractions. After he had left the Lungs for ſome time collapſed, the Animal ſeemed to be dying, and continued to expire though his Lungs were ſtill inflated; but then again he diſtended the Lungs more ſwiftly, by renewing the Motion of the Bellows, and by perforating the Lungs with a ſmall Lancet, into the Cavity of their Bronchia, the inflated Air continually eſcaped through the Punctures, and the Dog appeared to revive. In this manner he cauſed the Animal to be dying, and revived him alternately for twelve times together, keeping him betwixt Life and Death. From this Experiment it is manifeſt, that the whole Action of the Lungs conſiſts in changing the Magnitude and Figure of the Air-veſſels, which being alternately increaſed and diminiſhed, procure a free Paſſage to the Blood through the Lungs; which would not be

able

able to pervade this Viſcus if they were continually maintained in the ſame State of Reſt by the Air.

§. 608. Since therefore at the time of Inſpiration, the Air enters in a *larger Quantity* through the Glottis into the Lungs than before, it will extend them into larger Dimenſions (§. 603.), will overcome their natural contractile Force (§. 605.), and conſequently in this Action the Lungs will be paſſive.

[1] Take a Bladder full of Air, in which is faſtened a Tube; if now you apply your Lips cloſe to the Tube, cloſing the Noſtrils, you will ſee the Bladder collapſe in proportion as the Air is received out of it into the Lungs; and this quantity of Air may be meaſured by thoſe cylindric Veſſels which are uſed for Air-pumps. But all this Air continues in the Air-veſſels of the Lungs, ſince the ſanguiferous Parts of this Viſcus admit no Air; and therefore the more Air is inſpired, ſo much the greater will be the Capacity or Dimenſions of the Air-veſſels of the Lungs. Now in order to the Performance of this, it is neceſſary for the Lungs at the time of Inſpiration to be either inflated or leſs preſſed, ſince there is no other Method by which the Lungs can be expanded. But the latter of theſe is the true manner of Inſpiration; for in breathing I do not preſs the Air into my Lungs, but by dilating the Capacity of the Thorax, I diminiſh the Reſiſtance or Cauſes compreſſing the Thorax. Hence it follows that Reſpiration is performed by the Power of the Thorax, and not by that of the Lungs; and therefore it now remains for us to explain in what manner the Dilatation of the Thorax is performed.

§. 609. By

§. 609. By obſerving Inſpiration in a *living Perſon* [1], more eſpecially in one who is ſleeping, we perceive, firſt, that the Ribs, eſpecially the nine uppermoſt, *continuing* [2] in their Articulations with the Vertebræ, and in their Connection with the Cartilages adhering to the Sternum, do riſe up with their *arched* [3] Parts towards the *Clavicles* [4], in ſuch a manner that their Motion is chiefly to be obſerved in the middle of the Arch; but the three or four *lowermoſt* [5] Ribs, are at the ſame time moved downward and a little obliquely outwards, but ſo that the ſeventh, eighth, ninth and tenth of the Ribs with their cartilaginous Extremities, are as it were drawn *inward* [6]. 2. At the time the whole *Abdomen* [7] ſwells viſibly by degrees, during the whole Inſpiration, and is thruſt ſtrongly outwards. 3. At the ſame inſtant alſo the Capacity of the Thorax is increaſed, as is evident to the *Eye* [8], by *meaſuring it* [9] with a String or in a *Bath* [10], eſpecially by conſidering the mechanical Figure, Situation, Connection, and Articulation of the Ribs, which are diſpoſed to form the Thorax with great Artifice; concerning which you may conſult the Demonſtrations of *Borelli* [11].

[1] I have frequently made Obſervations upon the Reſpiration of Men and Infants ſleeping naked in the Summer-time, and alſo in lean Dogs ſleeping by the Fire-ſide, whoſe Ribs might be very plainly ſeen as they moved; for it is better to conſider

ſider this Action in the time of Sleep, that the vital Motion herein concerned, may not be diſturbed by the animal Motions.

[2] The Ribs remain articulated to the Vertebræ in this Action, becauſe their Ligaments do not permit them to recede; nor yet are they ever ſeparated from the Sternum.

[3] They intercept an Arch betwixt that Part which is articulated with the Vertebræ, and their cartilaginous Extremities.

[4] Towards the Clavicles in Man, but in Dogs they move towards the Axillæ.

[5] Obſerve a lean Infant in a profound Sleep, and you will perceive the nine uppermoſt Ribs ariſe ſlowly, ſtrongly and equably upwards; while the lowermoſt Ribs in ſome meaſure deſcend downward, and obliquely backward or outward from the Diaphragm, which in that Part is very fleſhy. All the Ribs therefore do not aſcend as is commonly imagined; and for this Reaſon it is that Nature has made the intercoſtal Muſcles after a different manner; but while the upper Ribs aſcend, the lowermoſt deſcend; and ſince at that time the Ribs are thruſt outward, ſo as to recede from the Middle or Center of the Thorax, therefore the Diſtance betwixt each Rib will be increaſed, the Thorax will be elongated and its Capacity enlarged.

[6] The cartilaginous Extremities of theſe Ribs are thruſt inward in the moſt violent Inſpirations, as in thoſe who are dying; for then Nature uſes all means to dilate the Thorax, and propel the Blood through the Lungs; for Death cannot take place before the Courſe of the Blood is interrupted thro' the Lungs from the right Ventricle to the left. In theſe Agonies therefore the Neck, Scapulæ, Clavicles, Back and Abdomen labour together by their conjunct Powers in a ſurpriſing manner, to enlarge the Capacity of the Thorax. After

[7] After you have expired the Air from your Lungs, take hold of your Waiſtcoat with your Hand upon the Abdomen, and you will perceive that during Inſpiration the Abdomen will ſwell and force the Cloaths out of your Hand. For at the time of Inſpiration the whole Lungs are inflated, the Capacity of the Thorax is dilated, and at the ſame time the Diaphragm deſcends towards the Abdomen, whoſe Cavity is therefore diminiſhed, and its Viſcera compreſſed at that inſtant.

[8] This is an Experiment which I have frequently tried upon myſelf. At the time of Expiration let a String be carried round the Thorax, and then let the Air be ſtrongly inſpired, by which means you will ſee how much more of the String is required to encompaſs the dilated Thorax; and that additional Portion of the String will be the Meaſure determining the Dilatation of the Thorax.

[9] In the Hound of that Species which run before the Wind, the Thorax is large, but the Abdomen is as it were cut out, and the more compreſſed as the Dog is fitter for the Courſe; and in ſuch a one we may ſee the Thorax dilate at the time of Inſpiration, the Abdomen receiving ſcarce any Alteration.

[10] If you fix yourſelf to a Beam in a Bath ſo as to be immoveable, without cauſing the Water either to aſcend or deſcend with a fluctuating Motion, and then gradually breathe in the Air, the Water will riſe proportionably in the Veſſel. For as the Bulk of the Thorax is increaſed by the inſpired Air, the Water will be obliged to aſcend higher; but will fall again to its former Mark when you have breathed out the Air. By this means the Difference betwixt the two Marks pointed out by the Riſe and Fall of the Water will determine the Quantity and Space taken up by the Enlargement

of

of the Thorax in Inſpiration, beyond what obtained in Expiration. But at the ſame time the Abdomen will ſwell downward conſiderably, from the Dilatation of the Thorax and Deſcent of the Diaphragm.

" The Ribs ſeem to be Bodies of no moment, but if you approach near, you will not perceive any one of the twelve, but what correſponds with the reſt in Fabric, Direction, Magnitude, the mutual Connection of their cartilaginous Extremities, and their Articulations with the Sternum and Vertebræ. You will find all of them ſo diſpoſed, that the largeſt of the Ribs, namely, the eighth and ninth will be in the middle and the moſt moveable; and thus the Thorax may be wonderfully dilated, ſince the Ribs are moveable as well upward as downward. But the upper Ribs which are neareſt to the Clavicles are leſs moveable, and the lowermoſt Ribs have likewiſe a leſs Motion in proportion as they are farther diſtant from the ninth Rib; the lowermoſt having little or no Motion, ſerves as a Baſis to ſupport the Diaphragm, and prevents it from deſcending or collapſing, as it is firmly attached to the laſt Ribs. The eleventh Rib has indeed a little more Motion towards dilating the Thorax, and the more do the Ribs move as they aſcend higher to the fourth or fifth counting upwards. One who attentively conſiders this will readily confeſs, that all this muſt be the Contrivance of Divine Wiſdom; namely, that the Thorax ſhould be capable of moving without changing the particular Fabric of its Parts, as *Bellini* obſerves. But all this Doctrine has been conſidered more at large by *Borelli*.

§. 610. But

§. 610. But alſo in this Action of the Ribs, the *Diaphragm* [1] is changed from its convex or hollow Poſition, which it before had, and being brought *downward* [2], it aſſumes a more plain or flat Figure; and this we are taught from the opening of living Brutes, as alſo from large Wounds inflicted upon the Abdomen in the human Species; and again, that this Change of Figure in the Diaphragm proceeds from a Contraction of its muſcular Fabric, we are taught by anatomically *conſidering* [3] this Part.

[1] The Diaphragm is a Muſcle whoſe fixed Part is all that conical Ellipſis which is made up by the Sternum, Loins, and ſeven lower Ribs. To the Margin of theſe Parts the Diaphragm is connected fleſhy, having its largeſt muſcular Portions ſeated behind towards the Vertebræ, being tendinous in its middle, to which in Man, the Pericardium very ſtrongly adheres. But this tendinous Part of the Diaphragm is higher than is commonly ſuppoſed, ſince a Wound inflicted upon the Thorax at the fifth Rib near the Sternum penetrates into the Abdomen. This Part therefore will be drawn down, while the muſcular Fibres are contracted, whence the Diaphragm which aſcended like an arched Roof into the Thorax, will be changed into an even Plane, ſo as to compreſs the Abdomen and thruſt it outwards, more or leſs in proportion to the Strength of the Reſpiration, and as the Cavity of the Thorax is more dilated. But all the Viſcera of the Abdomen are then preſſed by this incumbent Force of the Diaphragm againſt the tenſe and reſiſting Peritonæum. You will perhaps

perhaps ſay that it is from this Contraction of the Diaphragm, that the cartilaginous Extremities of the Ribs are moved downward and outward: but theſe Ribs are ſuſtained by the Serrati majores in ſuch a manner, that the whole Circumference of the Diaphragm deſcends, while its middle or tendinous Part only remains at reſt.

[2] It is ſomething wonderful that both the Cavity of the Thorax and Abdomen ſhould be enlarged at the time of Inſpiration, inſomuch that it is impoſſible for one to dilate the Thorax without enlarging the Abdomen likewiſe; for if the Abdomen be ſecured by Bandage, it will cauſe a difficulty of breathing, and you will be obliged to breathe more frequently to make up the want of large Inſpirations. All theſe Experiments ſhould be tried upon healthy living Animals, for in thoſe which are dying the Convulſions cauſe great Diſturbance.

[3] In the Memoirs of the Royal Academy of Sciences for the Year 1729, M. *Senac* has given us a good Figure of the Diaphragm, in which are repreſented Fibres placed round the Vena cava and Œſophagus, which Fibres ſeem to conſtringe thoſe Canals; yet does that Author deduce Conſequences oppoſite from thoſe which ought to follow from the natural Fabric of this Part, affirming, that Inſpiration may be performed by the Intercoſtals only, and that the Air which enters the Thorax is ſufficient to depreſs the Diaphragm.

§. 611. Since therefore there is no other Action concerned in Inſpiration than that of dilating the Thorax, it is evident that the Cauſe thereof muſt be determined by the Motion of the Ribs and Diaphragm, the Cauſes of whoſe Motions we are next to enquire after.

Inſpiration

Inſpiration then is a Dilatation of the Thorax made by an Alteration of its Figure, from a ſpreading of the Ribs and an Expanſion of the Diaphragm. If now the Lungs continue without being dilated while the Thorax is expanded, as ſometimes happens in an Aſthma, in that caſe a ſlight Vacuum is made in the Cavity of the Thorax, reſembling that made by the Air-pump of Mr. *Boyle:* but the Atmoſphere we know preſſes upon the Lungs with a Force equal to thirty-three cubical Feet of Water; and conſequently our Lungs muſt give way to ſo great a Preſſure, that is, they will be thus dilated. But in a living healthy Perſon the Lungs are always dilated, and equally diſtended together with the Thorax without ever forming a Vacuum, and without any Succeſſion of time betwixt the Dilatation of one and the other. When the upper Ribs are elevated the lower ones are preſſed backward and downward; and as the Sternum cannot give way inwards, therefore the Thorax will be dilated on all Sides and throughout all its Dimenſions.

§. 612. The ten ſuperior Ribs are incurvated or arched Bones, much more depreſſed in their middle than at their Extremities which riſe up; their Heads being armed with two Apophyſes or Protuberances covered with Cartilage, are articulated, 1. Into the cartilaginous Cavity of the Vertebræ, fixed backward on the Sides of their Bodies, or in the Body only of the firſt Vertebra of the Thorax. 2. They are articulated into a cartilaginous Sinus fixed in the tranſverſe Proceſſes of the Vertebræ; while the ſeven ſuperior

rior Ribs are alſo joined to the Sternum by the Interpoſition of arched cartilaginous Segments very elaſtic, in an *acute* [1] Angle upwards in the firſt Rib, almoſt at a right Angle in the ſecond Rib, and in the other Ribs forming an obtuſe Angle with the Sternum, in ſuch a manner that the Angles here formed by the Cartilages and Ribs with the Sternum *upwards* [2], is the more obtuſe as the Ribs are lower; in other words, the cartilaginous Segments aſcending from the Ribs enter the Sternum laterally in ſuch a manner, that the higher the Rib, the more acute or ſmall is the Angle of Inſertion, from the Concourſe of the upper Part of the Sternum. 3. But the ſixth, ſeventh and eighth Ribs join their cartilaginous Arches bending up to the Sternum, uniting with their Extremities, and adhering to each other at the bottom of the Sternum by broad cartilaginous Proceſſes. The two and ſometimes three lower Ribs being furniſhed with only one Apophyſis behind, are by that articulated into only one Sinus fixed in the Body of its correſponding Vertebra; and their Cartilages being not more compact than Tendons, do not reach the Sternum, but are inſerted into and diſappear in the Diaphragm and Cartilages of the next Ribs, and from hence they ſeem to direct, equally ſuſtain, and aſſiſt the Motion of the Diaphragm backward and downward.

[1] The Cartilage of the firſt Rib cannot move its Rib any way but upwards. The Cartilage of the ſecond Rib, which makes a right Angle with the

Sternum, gives it a Motion upward, and in ſome meaſure downward; the third moves only downward with a more ample Motion; and the fourth is ſtill more moveable downward, till the ninth, which is the moſt moveable.

[s] Namely, the eight or nine ſuperior Ribs; for among theſe there is often ſome Variation. They have a threefold Articulation, one to the Sternum, another to the Apophyſes of the Vertebræ, and a third, which is properly the affixed Point upon which they move as upon a Center, namely, the extreme Apophyſes of each Rib, which are articulated by a true Enarthroſis into a Fiſſure, ſeated in the two Bodies of the adjacent Vertebræ.

§. 613. The external intercoſtal *Muſcles*[t] ariſing from the lower Margins of the ſuperior Ribs, deſcend obliquely forward, and are inſerted into the ſuperior Margins of the next following Ribs throughout the whole Extent of their Margins, both among all the true and the ſpurious Ribs: but the internal intercoſtal Muſcles ariſing from the lower Margin of the upper Rib, at a diſtance from the Sides of the Spine of the Thorax, deſcend obliquely backwards acroſs the former Muſcles, and are inſerted into the upper Margin of the Rib next following below, throughout the whole length of the Bone and its Cartilage even to the Sternum.

[t] It is eaſy to conceive and explain the Motion of the Ribs, as performed by the intercoſtal Muſcles. It was neceſſary for theſe Muſcles to be diſpoſed in two different Series; for if Nature had provided only the internal Muſcles, they might indeed

indeed draw the Ribs towards each other, but then in their Action they would return the Ribs outward, ſo as to deform the Thorax. If the external intercoſtal Muſcles only were provided by Nature, they would in their Action have turned the Ribs inward ſo as to diſturb the Figure of the Thorax; whereas by the preſent Contrivance of them in different Series, they draw the Ribs together, while at the ſame time they preſerve the Parallelifm of them with reſpect to each other, without bending any of the Ribs ſo as to injure the Lungs. ——But, ſecondly, if all the Ribs were equally approximated towards each other, the Thorax could not be dilated; and therefore the firſt Rib is bent in a half Ellipſis, and ſo firmly articulated to the Sternum by a very ſhort Cartilage, that it with difficulty moves upward, but not at all downward. The ſecond Rib is ſtill a little more moveable than the firſt, and the third more flexible than the ſecond, and the fourth ſtill more than the third, down to the ſeventh, which is the moſt moveable both upward and downward. When therefore the intercoſtal Muſcles act and draw the Ribs towards each other, the firſt of them reſiſts without Motion, the ſecond aſcends toward the firſt, the third toward the ſecond, and ſo each of them following the inferior towards the ſuperior Ribs, whence the whole Thorax is dilated; ſo that the Figure of the Thorax is not changed whether the Ribs aſcend or deſcend, becauſe each of them are maintained in their due Parallelifm.. On the other hand, the Sternum cannot be preſſed inward, as being ſupported by and articulated to the cartilaginous Segments of the Ribs.

§. 614. But to the preceding we muſt add the *ſubclavian* [1] Muſcle, which ariſing fleſhy from the lower half of the Clavicle, where it is joined to the Spine of the Scapula, proceeds obliquely forward, and is inſerted into the upper Margin of the firſt Rib near the Sternum.

[1] The human Lungs are very large; and in general the Lungs are largeſt in thoſe Animals which are the moſt active, and which live with much Exerciſe. Hence there was Danger, leſt in violent Inſpirations the upper Ribs might be drawn downward, ſo as to impede the Dilatation of the Thorax. But Man as a moſt active Animal is furniſhed with Clavicles, which are two ſtrong Bones articulated each between the Sternum and Proceſſus acromion of the Scapula, ſo firmly that they cannot be drawn aſide any way. Theſe Bones are only to be found in the more active Animals, who have a free Motion of their anterior Limbs every way, ſuch as the Bear, Ape, Beaver, Dormouſe, Squirrel, Mole, Bat, Frog, *&c.* whereas other Quadrupeds are deſtitute of Clavicles, moving their Fore-limbs only forward and backward. From theſe Clavicles therefore in Man ariſe Muſcles, which deſcend to the firſt of the Ribs, which they elevate towards the immoveable Clavicles. Hence it is that in violent Inſpirations, the upper Rib is elevated and in a manner ſuſpended, juſt as if it had a proper intercoſtal Muſcle of its own, filling the intermediate Space betwixt itſelf and the Clavicle. The ſubclavian Muſcle therefore increaſes the Determination of the intercoſtal Muſcles upward, and occaſions the upper Ribs to aſcend only.

§. 615. If

§. 615. If then theſe Muſcles (§. 613, 614.) contract together, the firſt Rib is then *fixed* [1] by the Force of the Subclavian, though it is already ſufficiently firm by its own Articulation; and then the nine following Ribs are raiſed upwards and turned *outwards* [2], eſpecially in the middle of their Arches, but in ſuch a manner that they continue in their equable Paralleliſm, while in the mean time they depreſs the cartilaginous Segments which forcibly *reſiſt* [3] them; and thus is the Capacity of the Thorax conſiderably enlarged.

[1] The ſubclavian Muſcle draws the upper Rib towards the Clavicle, ſuſtains it immoveable, and prevents it from being drawn down by the firſt Series of intercoſtal Muſcles; and thus is the firſt Circle of the Ribs fixed and ſecured from deſcending.

[2] The human Thorax is formed ſo as to be narroweſt in its upper part, and broadeſt downward at its bottom; ſo that the Ribs are diſpoſed as it were in a conical Shape: and the ſecond Rib while it is elevated towards the firſt, is not raiſed by itſelf; but as its moſt moveable Point is in the middle of its Arch, therefore it will be there moſt elevated and turned outward, not ſo as to alter its Figure, but to increaſe its Diameter. By this means then the Plane will be increaſed, which perpendicularly interſects the Thorax. Suppoſe now the Ribs to be more equal Circles, they would then have certainly diminiſhed the Capacity of the Thorax; ſince a Circle moved round its Diameter either upward or downward, leſſens the contained Space, which is largeſt when the Circle is at reſt.

But in the preſent Caſe, the firſt Circle or the firſt Pair of Ribs are ſhorter than the ſecond, the ſecond than the third, and ſo on enlarging to the tenth; and therefore the drawing up of each Rib is a Dilatation of the Space which it contains.

* This Reſiſtance of the Cartilages is not eaſily underſtood, and yet hereupon is founded the whole Buſineſs of Expiration: Why then has Nature made the Extremities of the Ribs not bony, but cartilaginous at the Sternum? And why are thoſe Cartilages not articulated to the bony, but to the cartilaginous Part of the Sternum, or at leaſt with the cartilaginous Sinus's of the Sternum? We muſt obſerve that a Cartilage is the moſt elaſtic of all Parts in the human Body, and therefore after it has been compreſſed, it powerfully reſtores itſelf of its own accord. That the Ribs are truly Springs, *Veſalius* has taught us, from a play-full Experiment of Lads, who when they want a Ball that will fly back powerfully, they make one of the Cartilages of Fiſh cemented together; for a Sphere of this nature will fly back more than Metal itſelf. Nature has therefore made the anterior Extremities of the Ribs cartilaginous at their Connection with the Sternum; but theſe cartilaginous Extremities are not diſpoſed in the ſame Direction with the Ribs or Sternum, for the Cartilage of the uppermoſt Rib forms an obtuſe Angle with the ſame Bone, as it forms an acute one with the Sternum. Hence therefore while the Ribs are elevated, their cartilaginous Extremities are preſſed and reduced into a ſmaller compaſs by the Compreſſure; whereupon it re-acts or reſtores itſelf the more ſtrongly in proportion to the compreſſive Force, that is, as the Thorax becomes more dilated; and thus all the Force applied to the whole Rib is ſuſtained entirely by the cartilaginous Segment

ment of the ſame Rib. The Cartilages therefore endeavour to reſtore themſelves during the whole time that the Ribs are elevated.——The Inſpiration then of the Air is performed by the conjunct Action of the ſubclavian and all the intercoſtal Muſcles; ſo that their whole Force terminates in the Cartilages of the Ribs, which being incapable of Elevation from the Angle of Inſertion to the Sternum, are nevertheleſs overcome by the Action of the intercoſtal Muſcles, whoſe Action the Cartilages therefore return; that is to ſay, ſo ſoon as the intercoſtal Muſcles ceaſe to act, the Elaſticity of the Cartilages depreſſes the Ribs and reſtores them to their former Situations.

§. 616. The Diaphragm, before deſcribed (§. 86. N°. 1.) contracting itſelf into a Plane, does by that means powerfully dilate the Thorax and compreſs the *Abdomen* [1], while at the ſame time it draws the anterior Cartilages of the ſmall Ribs inward towards the Vertebræ, forcing likewiſe the two lower falſe Ribs downward, and diſtending or overpowering the abdominal Muſcles (§. 86. N°. 2.). But when the muſcular Fibres of the Diaphragm are relaxed, then the ſtrong elaſtic Force of the Pericardium and Mediaſtinum, ſuddenly pulls the convex Part of the Diaphragm towards the Throat; being in that Action much aſſiſted by the contractile Force of the Muſculi meſochondriaci, belonging to the Trachea and Bronchia of the Lungs; to which add the Deficiency of Air in the Cavity of the Thorax.

' A Perſon is able to force the Abdomen inward, and to expand or thruſt it outward, ſo as to make a great Difference betwixt its Capacity when expanded, and when contracted. This whole Difference proceeds from the Diaphragm, which is on all Sides attached to the falſe Ribs, and furniſhed with two ſtrong muſcular Crura or Appendices fixed on each Side of the Loins. When the muſcular Fibres of the Diaphragm contract all at one Inſtant, its ſeveral curve Lines are reduced to ſtraight ones, whereupon it deſcends as far as the connected Mediaſtinum and Diaphragm will permit, even till it has reached the utmoſt Limits of Inſpiration. But in the middle of the Diaphragm there is a tendinous Expanſion, which is not concerned in this Action of flattening the Diaphragm, which is performed by the muſcular or fleſhy Part only, whoſe chief Seat is upon the Loins; whence it will be drawn downward and towards the Loins. But this Deſcent of the Diaphragm is reſiſted by the arched Ribs; and therefore the moveable Ribs will be drawn down by the Diaphragm, while the Thorax is dilated in the Act of Inſpiration, becauſe their cartilaginous Extremities are attached to the tendinous Part of the Diaphragm, which is drawn by its muſcular Part. But this Action by which the lower Ribs under the Sternum are drawn inward and downward, appears moſt evident in thoſe who are dying; for then the poſterior Part of the Diaphragm, which is moſt firmly attached to the Loins, acts with all its Force. Now the ſhort lowermoſt Ribs are interwove with the lower and poſterior muſcular Part of the Diaphragm; while at the ſame time into theſe Ribs is inſerted the Serratus poſticus inferior Muſcle, which draws thoſe Ribs outward and backward, and prevents them from being forced too much inward by the Diaphragm;

phragm: and in like manner alſo the Serratus poſticus ſuperior in a more tranſverſe Poſition ſecures the upper Rib; and in this manner is Inſpiration performed.

§. 617. Theſe then ſeem to be the *only* [1] Muſcles employed towards Inſpiration; the Intercoſtals receiving their *Nerves* [2] from thoſe of the Back, but the Diaphragm receives its Nerves from the vertebral diaphragmatic and intercoſtal Nerves.

[1] By attentively obſerving a naked Perſon ſleeping in the Summer-time, you will perceive no Motion either in the Neck, Shoulders, or Arms, only the Thorax will be gently moved upward, and afterwards returned down again. At that time of breathing therefore, theſe Muſcles only act which move the Ribs, while the reſt are quieſcent. The ſame is alſo obſervable in apoplectic Patients, who have all the voluntary Motions abſent, the Organs of thoſe Motions being then paralytic.

[2] Theſe Nerves probably ariſe from the Cerebellum, or rather from that Part of the Medulla oblongata, which we now call the Spinalis, receiving its Nerves mixed with thoſe of the Cerebellum.

§. 618. The Capacity of the Thorax being thus enlarged, *nothing* [1] will compreſs the Lungs betwixt the Pleura and their Surface, and therefore the Air will enter through the Glottis and *inflate* [2] them, ſo as to bring them, or rather maintain them in *cloſe* [3] Contact with the Pleura and *Diaphragm* [4] (§. 604.); and by

by this means will be produced all thoſe Conſequences mentioned before (§. 197, to 200. N°. 2.).

[1] The Thorax indeed cannot be compreſſed, but the Lungs are preſſed againſt the Pleura with the whole Weight of the Atmoſphere; ſo that the Pleura does not compreſs the Lungs, ſince it is entirely faſtened to the Ribs, and receives itſelf the Preſſure of the Lungs.

[2] This is demonſtrated by Experiments made with the Air-pump, by which we ſee the Air ruſh with a great Impetus, ſo ſoon as a Paſſage is given for it to enter into a void Space; for into ſuch a Space the Air ruſhes a thouſand times more ſwiftly than the ſtrongeſt Wind.

[3] There are ſome who believe a *Boylean* Vacuum to be formed betwixt the Pleura and the Lungs at the time of Inſpiration, ſuppoſing the Lungs to be moved in that Vacuum; but this is a miſtaken Opinion, as we obſerved before (§. 607.); for the Lungs are preſſed againſt the Pleura by the whole Weight of the incumbent Atmoſphere, and while the Thorax is dilated, the Lungs are in the ſame inſtant expanded, without ever receding from the Pleura. Laſtly, the Lungs are never at reſt throughout the whole Courſe of Inſpiration, but are from the firſt to the laſt inſtant continually increaſing the Dimenſions of their Air-veſſels, and diminiſhing the mutual Contacts of their other Veſſels: for as we obſerved before (§. 200.) the Blood-veſſels are diſpoſed betwixt the Veſicles, ſo that theſe Intervals being increaſed they will be leſs preſſed, and conſequently the Lungs will receive ſo much more Blood from the Heart, in proportion as there is a leſs Reſiſtance in their Veſſels.

The

[4] The lower Part of the Lungs, which is compared to the Hoof of an Ox with reſpect to its Figure, follows the Motion of the Diaphragm; and therefore their Expanſion will be here greateſt, and the Circulation of their Blood ſwifteſt.

§. 619. In *this State* [1] of the Lungs and Thorax (§. 618.), the Air acts with an equable Force upon every Part of the Lungs, and being reſiſted by the Thorax, the Lungs reſt or ceaſe to be any farther expanded; now then leſs Blood will paſs through them, a leſs quantity will be moved into the left Ventricle of the Heart, and hence leſs will be ſent to the Cerebellum and its Nerves; to which add, that leſs arterial Blood will be impelled into the Diaphragm and intercoſtal Muſcles; ſo that thus the Cauſes dilating the Thorax will be weakened, whereupon the Elaſticity of the cartilaginous Extremities of the Ribs will depreſs thoſe Bones, being aſſiſted by the muſcular *Fibres* [2] which ariſe from the Sides and bony Ends of the Sternum within the Thorax, and are inſerted into the Cartilages of the true Ribs; at the ſame time alſo the Fibres of the diſtended Peritonæum and abdominal Muſcles will reſtore themſelves, and by preſſing upon the contained Viſcera will thruſt the Diaphragm now relaxed up into the Thorax; hence then the Thorax will be leſſened or compreſſed, and the Air forced out from the Lungs, which we call Expiration; after this again every thing ſucceeds as before-mentioned (§. 618.), and by

by theſe two Actions (§. 618, 619.) chiefly the Blood is accelerated and moved through the Lungs.

[1] When Inſpiration has arrived to its greateſt Extent, that is, when the Thorax dilates no farther, then the Lungs ceaſe to move, and no longer receive any change in their Figure. For as the Thorax is now ſuppoſed to be at reſt, ſo muſt likewiſe the Lungs, which are on all Sides in contact with the quieſcent Thorax. But as the Lungs now reſt, they no longer forward the Paſſage of the Blood through their ſanguiferous Veſſels; ſo that they do not now act as Lungs, but are of the ſame Nature with any other Viſcus. But we demonſtrated before (§. 208.) that the Maſs of Blood paſſes through the Lungs in the ſame time that it circulates through all the reſt of the Body; and therefore ſo ſoon as the Lungs ceaſe to tranſmit freely the Blood, the right Ventricle of the Heart will then begin to be incapable of tranſmitting its Blood through the Lungs: hereupon the Blood will be accumulated in the pulmonary Artery, while the pulmonary Vein will be empty, and conſequently the left Ventricle will receive leſs Blood, whence the Preſſure of the Blood upon the Brain and Cerebellum will be diminiſhed, whence the Secretion of nervous Juice will be leſſened, and the Cerebellum rendered incapable of tranſmitting a due Portion of Spirits to the intercoſtal Muſcles and diaphragmatic Nerves. But we know that every Muſcle acts only ſo far as it is inflated with Spirits by the Nerves; and therefore the intercoſtal Muſcles and Diaphragm will be rendered paralytic or relaxed. But the Ribs drawn up by the intercoſtal Muſcles and compreſſing their cartilaginous Extremities, will by the Elaſticity

ſticity of thoſe Cartilages be depreſſed to their former Situations, ſo ſoon as the intercoſtal Muſcles ceaſe to act; ſince thoſe Muſcles overpowered the Elaſticity of the Cartilages only without deſtroying the ſame. Theſe Muſcles then ceaſing to act, the elaſtic Cartilages will depreſs the Ribs, and theſe again will preſs out the Air from the Lungs, and force their Blood towards the left Ventricle; ſo that the Blood now flowing more freely and copiouſly to the Cerebellum, the neceſſary quantity of Spirits and Strength will return again by the Nerves to the Diaphragm and intercoſtal Muſcles, whence a Repetition of the ſeveral Appearances before-mentioned.

[2] Theſe muſcular Fibres ſeem to retain the Ribs in their Situations; and a Weakneſs in theſe renders the Thorax ſharp, as we obſerve in the Rickets. It is theſe Fibres that make Muſculus triangularis Sterni, as they are called by *Cowper*.

§. 620. At this Inſtant (§. 619.) the Blood being accelerated in its Motion, will begin to flow more ſtrongly and plentifully to the Cerebellum and reſpirative Muſcles, and conſequently theſe Cauſes will be renewed which actuate and contract the Diaphragm and intercoſtal Muſcles, whence the Inſpiration will be again renewed; and thus have we aſſigned the true, immediate and ſufficient Cauſes or Reaſons of this alternate vital Motion.

At this Inſtant the Lungs being compreſſed by the Thorax and Diaphragm, their venal Blood will be urged towards the left Ventricle of the Heart, which being more copiouſly filled, will ſend a greater quantity to the Brain, Cerebellum, and

and Muſcles of Inſpiration, which laſt will be therefore put in Action, and conſequently Inſpiration will return again. Hence we learn that Expiration is the State of Death; that is to ſay, the laſt Action in dying People is an Expulſion of Air from the Lungs by the retorting Force of the Cartilages, which are now become rigid with the Cold, and by that means exert their Elaſticity more powerfully.

§. 621. But beſides theſe vital Cauſes of Reſpiration, there are others ſubſervient to the *Will* [1], which are likewiſe applied to the Ribs, in order more powerfully to dilate and contract the Thorax. Thoſe which ſerve to dilate the Thorax, though deſigned for *other Purpoſes* [2], have nevertheleſs a ſhare in this Action, when they are determined thereto by the Will. The firſt of theſe Muſcles is the Scalenus primus, ariſing fleſhy from the anterior Part of the tranſverſe Proceſſes of the ſecond, third and fourth Vertebræ of the *Neck* [3], and deſcending obliquely forwards, is inſerted with its Tendon into the firſt Rib. In the next place the Scalenus ſecundus, ariſing fleſhy from the Sides of the tranſverſe Proceſſes of the ſecond, third and fourth Vertebræ of the Neck, deſcends, and becoming tendinous paſſes over the former, to its Inſertion into the ſecond and alſo the third Rib. Next the Scalenus tertius, ariſing fleſhy from the anterior and lateral Part of the tranſverſe Proceſſes of the ſecond, third, fourth, fifth, and ſixth of the Vertebræ of the Neck, is inſerted generally into

into the firſt Rib. By theſe Muſcles therefore the three ſuperior Ribs may be fixed, ſuſtained and elevated, that the Force of the intercoſtal and other Muſcles may not depreſs them in violent Inſpirations; nor is it any Objection to this, that they ſerve to bend the Neck or turn it round, becauſe if they act together in company with the Spinalis colli, the Tranſverſales colli, Interſpinales colli, Longiſſimus dorſi, and Semi-ſpinatus fixing or erecting the Neck, while the ſcaleni Muſcles act, theſe Scaleni muſt then elevate the Ribs of neceſſity; but that many of theſe Muſcles concur to dilate the Thorax in the moſt violent Reſpiration, is in a manner more than certain. 4. The *Serratus* 4 anticus minor, ariſing fleſhy from the Proceſſus coracoides of the Scapula, and deſcending obliquely forward, becomes broad, thin and fleſhy, and is inſerted into the anterior bony Part of the ſecond, third, fourth and fifth Ribs. 5. The Serratus anticus major, ariſing fleſhy from the Baſis of the Scapula, and becoming thick and broad as it deſcends obliquely forward, is inſerted as it were by indented fleſhy Portions into the eight ſuperior Ribs; two, three, four, or five of which fleſhy Indentations intercept the like Dentations of the obliquus externus Muſcle of the Abdomen. For if the Muſcles of the Scapula, the Trapezius, the Rhomboides, and Levator, fix and draw the Scapula upward and backward, retaining it immoveable, then the Ribs from the ſecond to the eighth will be ſtrongly

ſtrongly elevated by the Action of both the Serrati, as we plainly perceive to happen in the moſt violent Inſpirations. 6. Backward the Serratus poſticus ſuperior ariſing tendinous from the Spines of the two lower Vertebræ of the Neck, and three ſuperior Vertebræ of the Thorax, is inſerted by fleſhy Indentations into the Curvatures of the ſecond, third, and fourth Ribs, which are by this Muſcle raiſed obliquely upward. 7. To theſe add the Serratus poſticus inferior, which ariſing from the Spines of the Vertebræ of the Loins, and ſometimes alſo of the Thorax, is inſerted by muſcular Indentations almoſt into the middle of the Arch of the ninth, tenth, and eleventh Rib, as alſo into the Extremity of the twelfth; for this laſt aſcending upwards, almoſt from an horizontal Courſe with its Fibres, draws theſe laſt Ribs outward, downward and backward, ſo as to enlarge the Thorax, and prevent its Capacity from being diminiſhed by the Approximation of theſe Ribs, by the Contraction of the Fibres of the Diaphragm.

1 We have hitherto explained thoſe Powers which carry on the vital Reſpiration continuing in the time of Sleep; it now remains for us to explain the voluntary Actions which we experience to be employed in Reſpiration; for we are able to accelerate Reſpiration at pleaſure, and render it much larger than natural. According to the common Courſe of Nature, a healthy Perſon performs one Reſpiration within the Space of ſix or ſeven Seconds at moſt; but then the ſame Perſon may ſo accelerate his Reſpiration, as to finiſh it within the Space of one Second. There

[a] There was a certain learned Friend of mine, who endeavoured to prove that thoſe Muſcles which were not placed betwixt the Intervals of the Ribs, were not employed in Inſpiration; but it ought to be conſidered that every Muſcle which is attached to any of the Ribs, is not faſtened to a Part abſolutely immoveable; and therefore every Muſcle adhering to the Ribs may draw them according to their Direction, and the reciprocal Mobility of each towards ſome other Part, into which the other End of the Muſcle is inſerted; which other Part if it is more moveable than the Ribs, will be drawn towards the latter by the ſame Muſcle. When the Serrati antici Muſcles act, then the whole Scapula and Arm is by them drawn towards the Breaſt, becauſe the fixed or leaſt moveable Point of thoſe Muſcles is in the Ribs, the Scapula being more eaſily moveable; but when the Scapula is raiſed and fixed by the Action of other Muſcles, in that caſe, the Serrati may in ſome meaſure elevate the Ribs. Even let us ſuppoſe the Ribs to reſiſt with the Force of a hundred, and the Scapula with the Force of one; will it not from thence follow that the Ribs will approach one degree towards the Scapula, as that is drawn a hundred degrees towards the Ribs. Suppoſe again the Scapula to be elevated and fixed by other Muſcles, it is evident, that then the Ribs may move through a greater Space as they aſcend towards the Scapula, which being now fixed, the Ribs into which the fleſhy Indentations of the ſerrati Muſcles are inſerted, being then the moveable Point of thoſe Muſcles, while their fixed Point is in the Scapula. From hence it is evident, that the Thorax may be much more powerfully expanded by the Aſſiſtance of other Muſcles, than it can by the Action of the Intercoſtals only.

3 We are certain that the Scaleni Muſcles draw down the Neck towards the Ribs; but ſuppoſe the Neck to be powerfully erected or fixed by the numberleſs Muſcles of the Back, (as we ſee it may be fixed in Porters, ſo as to carry two hundred Weight laid upon their Head, without at all bending their Neck, to which add that a Man publickly ſhews himſelf, who raiſes an Iron Anvil by the Hair of his Head); that is to ſay, if the Neck is ſo fixed that it cannot be bent by the Scaleni which now act, it is then certain, that the whole Thorax will be drawn by theſe Muſcles towards the Neck. In the ſame manner it is evident, that all the voluntary Muſcles inſerted into the Ribs or detached from them into any other Part, perform a twofold Action; namely, when the other Parts are relaxed, and are not retained by contrary Powers, thoſe Parts will be then drawn more towards the Ribs than the Ribs towards them: but when theſe Parts are by other Powers more fixed, in that caſe the Ribs are obliged to move more towards theſe Parts, than they towards the Ribs; but it is well known to Anatomiſts that the Subclavian, Scaleni, and Serrati Muſcles are ſtrong enough to overcome the Reſiſtance of the cartilaginous Segments of the Ribs.

4 Theſe Muſcles are truly Antagoniſts to the oblique deſcending Muſcles of the Abdomen; and when the Scapula is raiſed by the Trapezius, Rhomboides, and Levator Muſcles, then the Serrati antici and poſtici draw the Thorax upward and forward. The Serrati poſtici ſuperiores cannot draw the Vertebræ towards the Ribs, and therefore they will move the Ribs outward, backward, and upwards towards the Vertebræ, from whence theſe Muſcles ariſe, and paſs almoſt in a tranſverſe

tranſverſe Poſition; and at the ſame time they prevent the three Ribs into which they are inſerted, from being drawn inward and downward by the Diaphragm, to which they are attached; and therefore each of the Serrati draw the Ribs from the Center of the Thorax, which is thus much more dilated than it could be by the Power of the intercoſtal Muſcles only. Hence it is that we ſee in dying People, a labouring in the Shoulders, Neck, and Arms, Nature being then incapable of ſufficiently dilating the Thorax by the Action of the intercoſtal Muſcles only, whence ſhe aſſembles all her Forces, in order to relieve the Anxiety. This laborious Reſpiration was well obſerved by *Hippocrates*, who underſtood it to be a mortal Sign, denoting that the Diſeaſe was ſeated near the Ribs, as a Pleuriſy or Peripneumony. It is eaſy to demonſtrate that theſe additional Forces externally applied to the Ribs to raiſe them, exert a much greater Power than the Intercoſtals.

§. 622. But the Action of the external and internal, *oblique* 1 and *recti* 2 Muſcles of the Abdomen (§. 86.) conſpiring together, *depreſs* 3 the Ribs and contract the Thorax; while at the ſame time the lower Serratus anticus Muſcle, as is evident from its Connection, reſiſts if it concurs with the Action of the *Sacro-lumbalis* 4, which is a very complex Muſcle and hardly to be deſcribed, conſiſting of a Series of muſcular or fleſhy Fibres, ariſing from the tranſverſe Proceſſes of the Vertebræ of the Loins, and from their Spines, from whence aſcending upwards into the Ribs, they are in-

ſerted or mixed with the fleſhy acceſſory Muſcles proceeding from the Ribs; whence it follows, that the Action of this muſt greatly aſſiſt in violent Expirations, the Abdomen being at the ſame time compreſſed by the *tranſverſe Muſcles* 5.

[2] We come now to enquire how voluntary Expiration is performed. In order to this we are to conceive the abdominal Muſcles ſubject to the Will; and therefore at the time of Expiration when the Ribs are reſtored by the Elaſticity of their Cartilages (§. 619.) that they voluntarily act and preſs the Diaphragm into the Thorax. In the next place let us conſider the Origin of the obliquus externus Muſcle, which being from the Os pubis tendinous, it is expanded round the Abdomen, and at laſt inſerted by fleſhy Indentations into the Ribs, betwixt the like Indentations of the Serratus anticus Muſcle; from whence you may eaſily underſtand that the Serratus and obliquus externus Muſcle antagonize each other, and that therefore the latter depreſſes and draws the Ribs inward, as they are drawn upward and outward by the Serratus.

[2] The fixed Point of the recti Muſcle is at the Os pubis, and their moveable Point at the Ribs, thoſe more eſpecially of them which are the moſt moveable, as alſo at the Sternum; theſe Muſcles therefore depreſs the Ribs, contract the Thorax, and preſs back the Contents of the Abdomen.

[3] The internal oblique Muſcle ariſes from the Margin of the Os ilium, almoſt as far as the Os pubis, and being inſerted tendinous in the Linea alba, it muſt conſequently preſs the lower Part of the Abdomen ſtrongly inward, when it contracts.

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[4] The Sacro-lumbalis Muſcle has certain Digitations inſerted into the Ribs, which it therefore draws downward and backward.

[5] The tranſverſe Muſcles of the Abdomen, if a right Line be drawn from where thoſe Muſcles ariſe at the Margin of the Os pubis and ilium to the Ribs, that Line will fall much within or beneath the Convexity of the Abdomen; for no living Creature can preſs back their Abdomen ſo far, but that it will project beyond the forementioned Line. If now the Abdomen is preſſed back againſt the Loins, they reſiſt that Action, and the Pelvis being in its own Nature immoveable, it follows that the abdominal Muſcles will preſs with their whole Force upon the Diaphragm; which being at that time paralytic or relaxed, from a Deficiency of the Spirits (§. 619.) will be therefore preſſed into the Cavity of the Thorax; ſo as to compreſs the Lungs and expel their contained Air as much as poſſible.

§. 623. In *Women* [1] the Sternum is more flat or depreſſed, the Clavicles are ſhaped more in a right Line, and the Thorax is leſs capacious, flatter before, and the cartilaginous Segments ſooner oſſify above than below; hence when they breathe, the Sternum riſes *upward* [2] and turns obliquely outward, the whole Thorax ſeeming as it were to ariſe; and for this Reaſon they breathe more freely when the Abdomen is diſtended.

[1] If you obſerve a Boy of a Year old and a Girl of the ſame Age, ſleeping in the ſame Bed, you will perceive that when the Girl breathes the

whole Thorax aſcends towards the Throat, whereas in the Boy the Thorax and Clavicles have little Motion. In an adult Man the Thorax is hardly moved in Reſpiration, whereas in a Woman the whole is drawn upward ſo as to recede from the Diaphragm; whence it follows that the Man breathes moſt with his Abdomen, and the Woman with her Thorax. If Nature had not made this Difference in Women, they would have laboured under a Difficulty of breathing during the time of their Geſtation, equal to what is ſuffered by a Man in an Aſcites; for in Pregnancy the diſtended Uterus fills the Abdomen in ſuch a manner, that it can very difficultly move, and therefore Nature has provided a greater Liberty in the Thorax, by rendering it very apt to dilate in the female Sex.

[2] Hence the Scaleni and flexor Muſcles of the Neck in Women, with all the Serrati and ſubclavian Muſcles, are to the Surpriſe of the Anatomiſt found ſtronger than in Men.

§. 624. From hence it appears that the voluntary reſpirative Muſcles are much *larger* [1] and ſtronger than thoſe ſubſervient to the vital or involuntary Reſpiration; whence it is that the Power of the former Muſcles can increaſe, diminiſh, or entirely ſuppreſs, both the Expiration and Inſpiration; of which Actions the Reſpiration is compounded.

[1] If you compare the Muſcles enumerated at §. 611, and 613, with the Powers of §. 622, and the Muſcles of §. 619, with thoſe of §. 621, you will perceive that the latter are at leaſt three times larger and ſtronger than the former, and that therefore

fore the voluntary Expiration muſt exceed the natural Inſpiration in the ſame proportion as to Strength; and again, at the time of Inſpiration, the Powers mentioned at §. 621, greatly exceed the Powers of natural Expiration. It is therefore evident we can by the Influence of the Will either ſuppreſs, increaſe, or diminiſh Reſpiration; one may be able to inſpire voluntarily even when Expiration would naturally follow, and alſo voluntary Expiration may take place when the vital or natural Inſpiration ſhould ſucceed. All this may be eaſily underſtood after having firſt demonſtrated that the voluntary antagoniſt Muſcles are much ſtronger than the involuntary Muſcles of Reſpiration.

§. 625. From hence we underſtand that there are not two ſucceeding Moments of Life in which the Veſſels of the Lungs retain the *ſame Figure* [1], Capacity and *Action* [2].

That there are alſo ſome Muſcles which act here *without Antagoniſts* [3], as if they had them; and therefore it appears that the Action of the Fluids moving theſe Muſcles, muſt be antagonized by the ſimple Reſiſtance and Elaſticity of the *Solids* [4].

There is therefore *no Neceſſity* [5] to ſuppoſe an alternate Action of the Humours in both Parts to produce their reciprocal Motions; ſince it will be ſufficient if that Action takes place in either of them.

Hence we ſee that the Influence of the Will is capable of ſuppreſſing the Force and Cauſes of Reſpiration, though it cannot *directly* [6] ſup-

preſs the Force of the Heart, whoſe moving Powers muſt be therefore *ſtronger* 7 and more conſtant or frequently in Action; yet is there a certain *Conſent* 8 or Relation betwixt the Contraction of the Heart and Number of Reſpirations; but according to what Rule is a Queſtion.

Hence alſo we perceive the Neceſſity of repeated Contractions in the Heart, and of repeated Reſpiration: but *how long* 9 they may be ſuppreſſed without Repetition, Life ſtill remaining, continues to be a Queſtion.

We ſee alſo why in a Fit of the *Aſthma* 10, Peripneumony, difficulty of breathing, and in the Agonies of Death, the Reſpiration is performed by the conjunct Action of the voluntary as well as the involuntary Muſcles moving the Thorax, in ſuch a manner, that we plainly perceive a *Motion* 11 in the Neck, Shoulders, Breaſt, lower Ribs, and Back?

Why in a perfect State of Health, the Body being at reſt and awake, the Reſpiration is performed very *ſlowly* 12, eaſily and ſilently; ſo that it is hardly perceived, though the Circulation of the Humours through the Lungs is then expedited?

Why the Reſpiration being accelerated by *Coughing* 13 or Sighing, increaſes the Motion of the Blood through all the Veſſels?

Why the firſt Act of Reſpiration is *Inſpiration* 14, and the laſt *Expiration* 15.

Whence it is that the Heart with its *Auricles* 16 and venous Sinus's *palpitate* 17 a long time

time after Reſpiration has ceaſed in thoſe who are dying?

And whence it is that an Air exceeding *heavy* [18], *light* [19], *moiſt*, [20], *dry* [21], *hot* [22], or cold, becomes unfit for continuing the Reſpiration and Life, which may be alſo ſaid of the Air which is too much rarified or compreſſed, or which is confined in a ſmall Compaſs, without being ſoon *renewed* [23].

[1] The Lungs are continually changing their Figure from the firſt Moment of Inſpiration to the laſt Pitch of that Action (§. 200.). All the time of this Action the Thorax is continually dilated, and at the ſame time alſo the Lungs are continually expanded cloſe to the Thorax which they never deſert, and thus in the Expanſion of the Lungs the Air-veſſels and Blood-veſſels are removed to larger Angles from each other, are ſet at liberty or enlarged, and more freely diſpoſed to receive the Blood from the right Ventricle of the Heart. For the inſpired Air repels the Veſicles from their mutual Contacts, ſo as to make way for the Reception of the Blood into the Branches of the pulmonary Artery, which being a flexible Canal neceſſarily changes its Figure in the Elongation; but ſince it is impoſſible for it to be diſtracted equably in every Part of the Lungs, there will be ſome Parts more contracted than the reſt; for if a membranous conical Tube is extended longitudinally in a curved Direction, ſome Part of it will be always complicated or more preſſed together, whence its Figure will be every Moment changing. The ſame is alſo true with reſpect to the Veins. But in Expiration alſo all the Veſſels are every Moment

ment contracted into a leſs Compaſs, and conſequently changing their Figure. Laſtly, the Lungs are at Reſt for a ſmall ſpace betwixt Inſpiration and Expiration; but the Air at that time received in the Lungs is either retained or elſe allowed a free Exit through the open Glottis. If it be retained, the Blood being always hotter than the Atmoſphere in which we live, will rarify the Air, ſo as to make it preſs more forcibly upon the pulmonary Blood-veſſels, which Preſſure will be more and more increaſed as the Air is longer retained, whence the Capacity of the Blood-veſſels will be diminiſhed. If on the other hand the Air has a free Exit from the Lungs, the latter will every Moment ſuffer an unequal and tremulous Motion while the rarified Air is expelled. What has been here ſaid concerning the Figure of theſe Veſſels, may be alſo applied to their Capacity; for when the Lungs are expanded the Arteries are larger, and when they are contracted, the Blood-veſſels are every Moment diminiſhed: but this Alteration is alternate and perpetual, and therefore we may ſafely affirm there are not two Moments of Time, in which either the Blood-veſſels or Air-veſſels of the Lungs continue in the ſame State.

[2] This Action of the Veſſels is no more than a Contact and Preſſure of their concave Surface againſt the convex Superficies of the Juices, which being in this Caſe forced through Canals varying their Figure and Capacity every Moment of Time, it follows alſo from thence that the Action of the Veſſels upon their Humours will not be two Moments alike.

[3] Every Muſcle during Life is continually diſtended by the nervous Juice and arterial Blood, ſo as to be held in a perpetual Conatus or Inclination

nation to draw the moveable Part into which it is inſerted towards the more fixed or leſs moveable Part; and therefore that the Muſcle thus inclined to Contraction during Life might not perpetually act, another Muſcle was required to incline with an equal Force towards oppoſite Parts, that is to ſay, it was neceſſary to keep one Muſcle antagonized or in Equilibrio by another. For Example, Suppoſe one Tendon is inſerted into the Back of the laſt Joint of a Finger, the Fleſh will draw that Tendon ſo as to keep it continually endeavouring to extend the Finger; but if another Muſcle is inſerted within the ſame Bone, continually endeavouring with the ſame Force to bend the ſame Finger, in that caſe it will be neither inflected nor extended, provided the Will makes no Addition to the Power either of the flexor or extenſor Muſcle, for ſo long will the Finger be kept in a mean State betwixt Flexion and Extenſion, the Equality and Contrariety of the Forces in the Muſcles deſtroying their Effect. But ſuppoſe now the flexor Muſcle to be ſuddenly paralytic or inactive, while the extenſor continues to act with the ſame Force, in that caſe the Finger will be ſuddenly extended, as with a ſort of Convulſion; or, on the contrary, it will be in like manner violently inflected, if the extenſor is paralytic, while the Action of the flexor remains entire. This then is what we intend by the antagonizing of one Muſcle with another. But the Intercoſtals have no Muſcles to antagonize them in this manner, the cartilaginous Segments of the Ribs ſupplying that Office by their Elaſticity, which reſtores the Ribs to their former Situations, after they have compreſſed the Cartilages by the Action of the intercoſtal Muſcles, which is no ſooner over but the

the Cartilages begin to exert their elaſtic Force and depreſs the Ribs. But thoſe Animals which carry their Head in a prone Poſture, have the Muſculus triangularis ſterni much larger within the Thorax, which Muſcle ariſing from the Sternum, is inſerted into the Extremities of ſeveral of the Ribs and their Cartilages, which it ſerves to depreſs, ſo as to aſſiſt their Elaſticity and antagonizing Force.

[4] Thoſe Muſcles which antagonize others, prevent the Action of their Opponents, becauſe they are inflated with Juices; but the intercoſtal Muſcles are oppoſed by the Elaſticity of the Cartilages, which proceeds only from the Force of the Solids, and does not depend upon any Influx of Juices; and therefore it follows, that a determinate Influx or Re-action of the Fluids is not abſolutely neceſſary to antagonize Muſcles.

[5] This may ſeem a Paradox to ſome, becauſe Anatomiſts uſually teach, that every alternate Motion reſults from an alternate Influx of the Juices, detached ſometimes to one Muſcle and ſometimes to another; and this indeed is true whenever there are Antagoniſts: but when the Antagoniſt is a Body re-acting only by the Elaſticity of its Solids, in that caſe this univerſal Affirmation does not hold true. The Heart and Cerebellum propel their Juices equably into all the Muſcles of the Body, which are therefore equally diſtended. The intercoſtal Muſcles are not filled with a greater Force by the Heart, than any other Muſcles, but theſe Muſcles elevate the Ribs, which are reſiſted by the elaſtic Cartilages, when they become ſtronger than that Reſiſtance, by a more copious Influx of the nervous Juice; for ſo long does their Power overcome the Reſiſtance of the Ribs, reſulting from

from the elaſtic Cartilages. But when the Actions of the intercoſtal Muſcles fix the Thorax immoveable, all the Veſſels of the Lungs are retained in the ſame Situation, whereupon their Force ceaſes, and ſome Part of the nervous Juice flowing to the intercoſtal Muſcles will be deficient; and therefore the elaſtic Cartilages then depreſs the Ribs without any Aſſiſtance from a nervous Juice. Hence it is evident, that Antagonization may be performed only if a Muſcle acts on one Side from an Influx of the nervous Juice, and on the other Side if there is an Elaſticity of the Solids.

[6] We are capable of altering the Reſpiration without changing the reſt of the Body, that is, we can increaſe, diminiſh, or ſuppreſs it at pleaſure; but we cannot thus alter the Action of the Heart without firſt changing the Condition of the whole Body.

[7] The Action of the Heart is ſtronger, inaſmuch as it is not obedient to any antagoniſt Muſcle; for the Heart continues to move even after Death, which the Diaphragm and intercoſtal Muſcles do not.

[8] I have made numerous Experiments in relation to this Conſent betwixt the Lungs and Heart, more eſpecially faſting, ſitting ſtill under a Calmneſs or Quietneſs of Mind, *&c.* under which Circumſtances I have remarked the Number of Pulſes made in the Space of an Hour, which in a healthy Perſon anſwer to 3600, but in Fevers, they amount to between 6 and 8000. But the Pulſe is a Dilatation of the Artery, anſwering to each Contraction of the Heart; of which if you doubt, apply one Hand to the left Breaſt, and the other to the carotid Artery, whence you will find that each of them ſtrike the Finger at the ſame Inſtant.

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The Number of the Pulſe is therefore the Number of Contractions made by the Heart. In the next place attend to the Number of Reſpirations made in a given time with Moderation or without hurrying, and you will perceive the determinate Space of each Reſpiration, meaſured by the Clock to anſwer to about eight Pulſes in a healthy Perſon. It will be alſo then eaſy for you to compute the quantity of Blood in proportion to the Heart and Lungs, which is tranſmitted from the right to the left Ventricle of the Heart through the Lungs at each Reſpiration, namely, amounting to about twenty ounces, ſuppoſing two ounces propelled by each Syſtole of the Heart into the Aorta. For betwixt the time of Inſpiration and Expiration, the Lungs are once filled and once emptied; and there is a determinate Ratio always obtaining betwixt a perfect Reſpiration and Pulſation, or betwixt the Syſtole and Diaſtole of the Thorax with the Syſtole and Diaſtole of the Heart. I have frequently tried theſe Experiments upon myſelf, till I have been afraid of carrying them too far. But if the Air be quietly retained in the Lungs, the Pulſe will be a little accelerated, but it will be retarded ſoon after; and even if you perſiſt obſtinately in retaining the Air, the Pulſe will afterwards be quite imperceptible to the Touch. Therefore when Reſpiration is diminiſhed, ſo is likewiſe the Action of the Heart; but by ſtrong and ſudden Reſpirations the Pulſe will be accelerated, and even rendered febrile, only by rendering this alternate Action of Expiration and Inſpiration more ſtrong and frequent. It is eaſy to enumerate the Numbers of the Pulſe and Reſpiration in a given time in an Infant ſleeping, when you will perceive a certain Reſt after each

full

full Reſpiration, compounded of Inſpiration and Expiration: after this wake the Child, and you will perceive the Pulſe and Reſpiration performed quicker than before; and therefore the Action of the Heart being increaſed, ſo likewiſe will be that of the Lungs, and the reverſe; whence there is evidently a conſtant Proportion in the Numbers of Action of the Heart and Lungs.

[9] This Queſtion may be anſwered two ways, according as you demand either how long the Air may be retained while the Glottis is open, or how long while the Glottis is ſhut? I have made frequent Experiments of this nature upon healthy People, and have obſerved many things abſtruſe relating thereto. I have drawn in a moderate quantity of Air, by retaining which I found that Life could not long be ſuſtained in that State; for the inſpired Air retained by ſhutting the Glottis, or Noſe and Mouth, does not reſt, but performs the ſame Action as if you continued to inſpire more Air; that is to ſay, it rarifies by Heat, and diſtends the Air-veſſels of the Lungs, ſo as to reſiſt and expel the Blood. But the Blood expelled from the Lungs is conveyed only to the left Ventricle of the Heart by the pulmonary Vein, while that in the pulmonary Artery ſtagnates in its ſmalleſt Branches, whence for a ſhort time the Pulſe becomes accelerated. Thus may Reſpiration be ſuppreſſed for ſome time without danger of Suffocation, namely, until the Air is ſo rarified by the Heat of the Blood that it can expand no farther; for then the venal Part of the Blood being evacuated from the Lungs, while the arterial is not tranſmitted into the Vein, the left Ventricle of the Heart from thence ceaſes to be ſupplied, whereupon the Animal muſt begin to die, ſince the

the right Ventricle of the Heart is not ſufficient to propel the Blood. In this manner the Slaves of *Angola* often ſuffocate themſelves by retaining their Breath. But it does not follow therefore that no Blood is tranſmitted through the Lungs while the Breath is retained; for ſuch a Portion of it continues to paſs through the Lungs, as their Veſſels will tranſmit without Reſpiration, and much more Blood paſſes through the Arteries and Veins of the Lungs at that time, than if the Heart was at reſt. But in this caſe the Lungs tranſmit no more Blood than what any other Viſcus would of the ſame Bulk in proportion to the reſt of the Body; juſt in the ſame manner as in the Fœtus, the Lungs receive no more Blood than is proportionable to their leſs Reſiſtance which they afford with reſpect to the Blood flowing into the Aorta; but this quantity of Blood paſſing through the Lungs as in a Fœtus, is too ſmall to maintain Life in the Adult, unleſs the Foramen ovale and Canalis arterioſus continue open.

[10] Do but obſerve an aſthmatic Patient breathing in the Fit, and remark how he labours with his Shoulders, Neck, Back, *&c.* in order more largely to dilate the Thorax, and to render the Action of the ſerrate and ſcaleni Muſcles more powerful.

[11] The human Body is ſo framed by its Creator, as to be always endeavouring to keep in the ſame State in which he firſt made it; and hence what *Hippocrates* calls Nature, is the Effect of the Structure of the Parts in the human Body, ſo framed by its Creator as to continue in the ſame State ſo long as its Fabric remains unaltered. Thus therefore has the Creator made the Thorax capable of receiving a ſtronger Action, in proportion as more

more Blood is to be tranſmitted through the Lungs in a given time, or in proportion as the Veſſels, or the Blood itſelf, afford a greater Reſiſtance to its Courſe through the Lungs. If therefore the quantity of Blood is determined, which can be freely tranſmitted through the Lungs of a healthy Perſon at Reſt, as the Blood in the ſame Perſon will be accelerated by Exerciſe ſo as to increaſe the Maſs which is to pervade the Lungs, by ſending back to the Heart the Blood, which before ſtagnated in the Veins, in that caſe there will be twice as much Blood to be tranſmitted in the ſame time; or if there is any Cauſe which gives twice as much Reſiſtance to the Lungs, or to the Blood, in all theſe Caſes the Reſpiration will be twice as large: and if the Blood is to be tranſmitted ten times ſwifter, to ſupply the left Ventricle with its due quantity in a given time, the Reſpiration will be ten times quicker; that is to ſay, the ſcaleni, ſerrati, rhomboides, cucullares, and other Muſcles, all of them conduce to accelerate and enlarge the Reſpiration, in order to enable the Lungs to tranſmit more Blood in the ſame time. But it is the ſame thing in effect, whether the quantity of the Blood or the Reſiſtance be increaſed; for if the Lungs themſelves become impervious, more or leſs the Reſiſtance will be proportionably increaſed, and the Muſcles of Reſpiration will be obliged to labour more in proportion, as we ſee in Aſthma's from a Scirrhoſity of the Glands, an Infarction of the Veſicles, a convulſive Conſtriction, *&c.* of the Lungs. Hence when the Blood begins to ſtagnate and thicken in Death, or in a Peripneumony, the voluntary Muſcles of Reſpiration labour with great Violence, and afford a frightful Spectacle,

that they may enable the Lungs to tranſmit ſome Part of the Blood. In ſuch a Perſon you will ſee the whole Thorax aſcend while the Diaphragm at the ſame time is drawn violently downward, every Part throughout the whole living Body alſo conſpiring to promote this Action, and to procure ſome Relief of the Maladies which cauſe theſe Agonies.

[12] Among all the Signs of good Health, the principal is a ſlow Pulſe and Reſpiration, the latter being performed without any viſible Motion of the Thorax or Abdomen, and without any audible Noiſe. For by theſe Signs we know that the Lungs are moſt ſlowly inflated, that they reſt and that they empty themſelves; but this Slowneſs demonſtrates an equable Motion of the Blood without any Obſtruction or Reſiſtance; and that the Blood does not ſtagnate, thicken, nor meet with any Obſtacle to impede the equable Circulation of the Humours through all the Veſſels of the Lungs.

[13] When a Vein has been opened by a Surgeon, the Blood often does not ſtart out, but if you order the Patient to cough, it inſtantly flies forth in a full Stream. It is therefore evident, that the Courſe both of the venal and arterial Blood is promoted by the Action of the Lungs, and that their Action is increaſed by a deep Inſpiration and a ſtrong Expiration; but ſuch is that Inſpiration, which we call Sighing; and therefore that as well as Coughing muſt evidently accelerate the Motion of the Blood. In a Pleuriſy when the Blood ceaſes to ſtart out from the Orifice of an open Vein, let the Patient ſigh, and the Blood will flow forth ſwiftly enough; but

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to this Action the Patient will not be inclined, to avoid the Pain, and therefore the Surgeon may order cold Water to be ſprinkled on his Face, that the Veſſels may contract and forward the Courſe of the Blood; or he may adminiſter ſome warm Wine, or let the Patient ſmell to ſome hot Vinegar, whoſe acid Fumes being drawn into the Lungs, will excite a laſting and ſtrong Cough, which will cauſe the Blood to flow faſt enough. For by Expiration the venal Blood flows more ſwiftly from the Lungs into the left Ventricle of the Heart, which will therefore propel a greater quantity of Blood into all the Arteries of the Body, and from thence the Veins will receive more Blood from the Arteries.

[14] When the Fœtus firſt comes forth from its Mother's Womb, its Lungs and Thorax do not differ from thoſe of an Adult, except in having the Foramen ovale and Canalis arterioſus. But the ſame Fœtus has no Air at all in the Thorax; but, on the contrary, there is Water in that Space which ſome ſuppoſe to contain Air. Nor yet does the Air enter the Lungs at the Birth ſpontaneouſly or by its own Weight, as I formerly believed with *Pitcairn* and *Baglivi*, but am now convinced of the contrary; for I have ſeen that the Lungs of a Fœtus after Excluſion are not diſtended with Air, though the Glottis remains quite open; and therefore it follows, that the Air enters the Lungs of the Fœtus, becauſe its Thorax is dilated by the Muſcles proper to Reſpiration. The firſt Action therefore of the Fœtus or Infant upon coming into the World is to dilate the Thorax, which is afterwards ſpontaneouſly contracted ſo as to cauſe Expiration, as we before obſerved. But why does

the Fœtus break its including Membranes, that it may breathe? Whether this is done with Deſign I cannot determine; but this is certain, that the Infant kicks and ſtruggles till it has burſt the Membranes and breathed Air, and that after it has once breathed, it remains quiet enough.

[15] To expire or give up ones Soul, is a Phraſe ſynonomous with Death in all the Languages of the World, becauſe this is the laſt Action of the Body, which is not performed by any vital or voluntary Power in ourſelves, but only by that Force which is in common poſſeſſed by all other inanimate Bodies. This Action therefore is exerted becauſe the vital Powers ceaſe to act, and the intercoſtal Muſcles becoming paralytic, the cartilaginous Extremities of the Ribs, do by their own Elaſticity unbend themſelves and depreſs thoſe Bones.

[16] In a Dog which has been opened alive, the Heart ceaſes to move, but then a ſmall tremulous Motion continues in its Auricles, which ſeem to undulate, namely, becauſe the Heart keeps warm longer than any other Part, whence the Auricles continue to evacuate themſelves in ſome meaſure into the Heart, which is not yet become rigid.

[17] Even this Palpitation is often obſerved after the Animal is really dead. The human Body has Veſſels and Fibres which vital Warmth render very large; for Heat or Warmth equably expand all Bodies throughout their Dimenſions: but in a dying Perſon the Heat gradually departs, until the whole Body acquires the Temperature of the Atmoſphere, which is not ſufficient to ſuſtain Life in any Animal; but this cooling of the Body in

Death

Death proceeds from without inwards, that is to ſay, the external Parts in contact with the Air become cold firſt, while the more interior Parts remain ſtill warm and dilatable. But the Heat of the Body we know is greateſt at the Heart; and therefore the Veins contracted by the Cold, will derive the Humours from all Parts of the Body towards the Heart, ſo as to render it capable of continuing its Motion for ſome time longer. Hence in thoſe who appear with a red and turgid Face while dying, their Face will look pale and flaccid after they are dead, when the Body is quite cold. But even in ſuch a dead Body, the Heart may be excited to palpitate by injecting Water into the Vena cava; and therefore theſe Motions in Death ariſe from the Contraction of the Veins occaſioned by the Cold.

[18] A heavy Air preſſes more upon the Veſicles of the Lungs as it exceeds more in Weight; but in proportion as their Veſſels are more preſſed, ſo are the Blood-veſſels more compreſſed. When therefore the Air is as heavy again, the Veſſels of the Lungs will be preſſed with twice as much Force againſt the Pleura, whence they will be contracted or leſſened, ſo as to reſiſt the Blood from the right Ventricle of the Heart, and this ſtronger and ſtronger, till they at laſt tranſmit no Blood at all.

[19] A light Air preſſes leſs upon the Veſicles of the Lungs, which are therefore leſs diſtended. That is to ſay, the Lungs continually exert their contractile Force, but remain continually dilated cloſe to the Pleura, becauſe the contractile Force of the Muſculi meſochondriaci is leſs than the diſtending Force of Air in the Lungs. Let the Air then preſs upon the Lungs with a Force twice as

weak, and then the Muſculi meſochondriaci will be twice as ſtrong, will contract themſelves with twice the Power, and act as we ſee in a ſpaſmodic or convulſive Aſthma, ſo as to ſuffocate the Patient by a Conſtriction of the Lungs.

[20] A moiſt Air is ſo pernicious, becauſe it fills the whole Lungs with inelaſtic Vapours.

[21] A dry Air is injurious by criſping up the pulmonary Veſſels.

[22] A hot Air is always light, but a cold Air has always the Properties of a heavy Air.

[23] This I muſt confeſs is very obſcure and not eaſy to be underſtood. Every Animal or even Vegetable we are aſſured from a thouſand Experiments, will die when included in a ſmall quantity of Air which is not renewed. If you ſow good Seeds in the beſt Earth, and adminiſter the moſt convenient degree of Warmth which is neceſſary to raiſe the Plants in a Veſſel full of Air, if you do but ſtop up that Veſſel, ſo that no Air can enter into it or paſs out from it, thoſe Seeds will not grow, and thoſe Plants which vegetated in open Air will here languiſh and die. Again, place any Animal in a Glaſs full of the beſt Air, and do but cloſe the Glaſs, and you will ſee the Animal periſh in a ſhort time, even if it is but a Fly included in a large glaſs Sphere, or a Sparrow ſhut up in a glaſs Veſſel capable of holding a hundred of theſe Birds. If you place a Thermometer in that Veſſel the included Air will appear of the ſame degree of Heat with that of the Atmoſphere, only obſerve this, that the Air will have loſt about $\frac{1}{14}$ part of its Elaſticity which is deſtroyed by the Animal. Is not that therefore the vital Spirit ſuppoſed by the Alchymiſts to reſide in the Air, which

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is conſumed by our Breath, and which muſt be perpetually renewed through the whole Syſtem of Beings? for without it is thus renewed, the Air, ſay they, having loſt its vital Spirit is not ſufficient to ſupport Life. This vital Spirit, ſay they, can be found by none but a true Philoſopher; but no one can demonſtrate what this vital Spirit is more than the Elaſticity of the Air: But I ſhall perhaps ſpeak more concerning this in my publick Lectures, when I come to treat concerning the Cauſes of ſudden Death.

FINIS.

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